VHF
COMMUNICATIONS

Digital stepped attenuator for up to 2.4GHz
Alexander Meier, DG6RBP

Contents

There are lots of interesting articles in this issue from theoretical to practical so I hope there is something for everyone. There is even an article form me that I hope will inspire other readers to write about their own projects and send them to me to publish. I am always interested in new articles and will help anyone to format an article to make it suitable for publication.

73s - Andy

Rafal Orodzinski, SQ4AVS

Low cost, wideband divide by 64 prescaler from 0.05 - 8GHz

1.0
Introduction

The number of divider ICs available is continually growing. They can be obtained for increasingly higher frequencies with many division factors but the biggest disadvantage of most prescalers is cost. One very good IC that can be used as a prescaler is the ADF4007 from Analog Devices. The ADF4007 cost only €5 in Poland. It is a parallel loaded PLL for up to 7.5GHz. It can also be configured as a prescaler.

2.0
Circuit description

In the schematic (Fig 1) the ADF4007 is programmed to divide by 64. They have a very wide frequency measurement range, the prescaler was tested over the range 0.05 - 8GHz. The sensitivity as a prescaler was tested, thanks to Stefan, SP9QZO: 8GHz, 350µW; 7GHz, 100µW; 6 - 2GHz <= 80µW. I have not measured the sensitivity of this prescaler in the lower frequency range but when I

use my transceiver on 70cm with an output power of 1W; I can measure the frequency with small 30cm antenna at a distance of 1m. The division factor can be set to; 8, 16, 32 and 64. The ERA1 protects the ADF4007 from being destroyed by strong signals. It is not recommended to replace this IC with a similar IC such as the ERA2 because they give worse sensitivity. The 33kΩ resistor, R33, stops the prescaler from oscillating, but it also reduces sensitivity by more then 10dB. I use a lot of power supply decoupling. Resistor R4 protects the output of the prescaler. The LM1117 is a low cost low dropout 3.3V power regulator. I have also added a detector diode, D1 as used in the S53MV frequency counter. C17 is a high quality capacitor; you not must use low quality capacitors for the detector (you must use high quality capacitors).

3.0
Construction

The circuit is built on a small double-sided PCB, 44 x 37mm, made from 0.5mm FR4 material with a solder mask and plated through vias. The PCB layout is shown in Fig 2 and views of the top
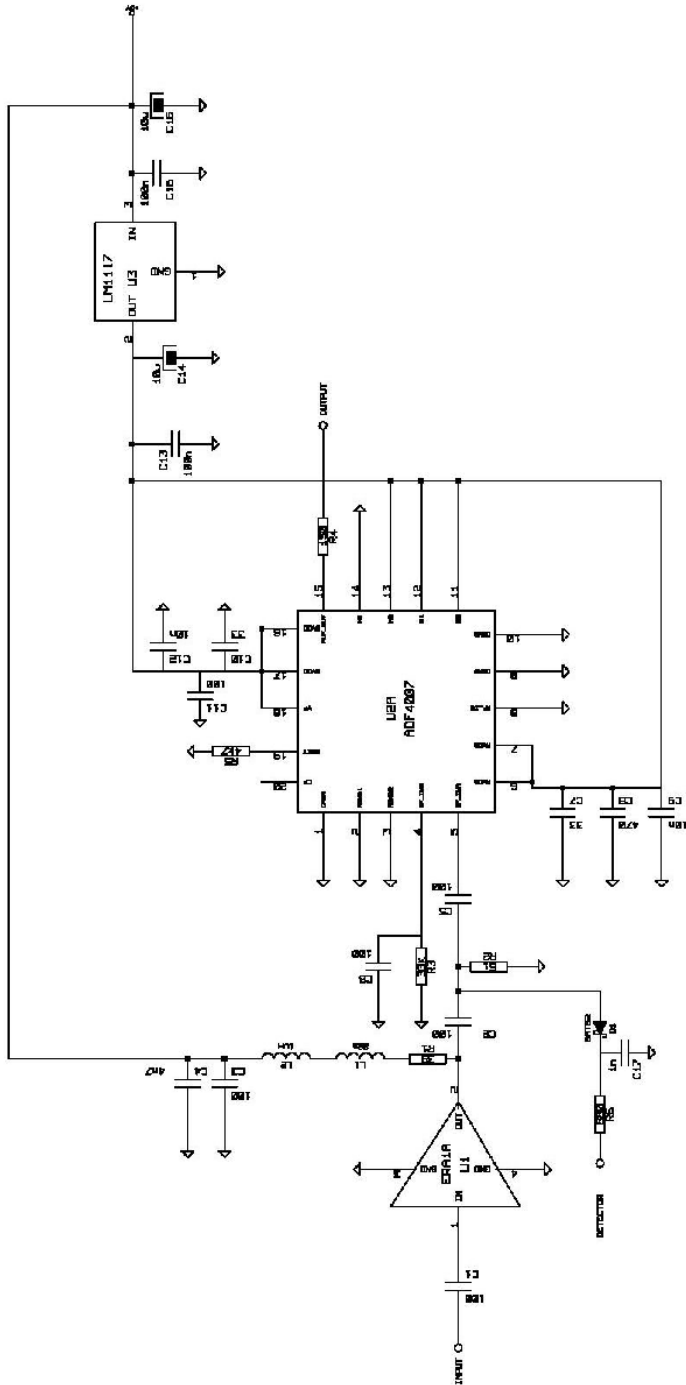
Fig 1: Schematic diagram of the 8GHz divide by 64 prescaler
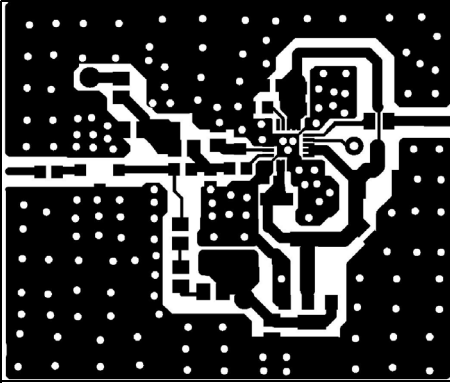
Fig 2: PCB layout for the 8GHz divide by 64 prescaler.

Fig 4: Bottom side of the PCB for the 8GHz divide by 64 prescaler.

and bottom side if the completed PCB are shown in Figs 3 and Fig 4. The components required for a PLL, shown in the application notes, are not fitted to this PCB. Because the ADF4007 has a small package, it is a very good idea to use a solder mask on the PCB, this makes soldering much easier. Fig 5 shows a close-up of the IC fitted to the PCB. I use a hot air gun to fit this IC. I have built more than 10 of these without any problems they have different configurations, such as dividers or PLLs on different PCBs.

If the circuit is working correctly the voltage on the input of the ADF4007

should be 1.8V and the voltage on the output (without resistor R3) should be 1.0 – 1.3V. Without R3 the prescaler will oscillate in the range 6.5 - 7GHz.

4.0

Parts List

C1, C2, C3, C5, C6, C11	100pF (0603)
C4	4.7nF (0805)
C7, C10	33pF (0603)

Fig 3: Top side of the PCB for the 8GHz divide by 64 prescaler.
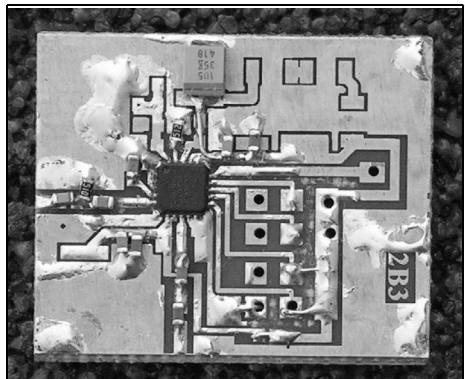
Fig 5: Close-up of the ADF4007 IC.

C8	470pF (0603)
C9, C12	10nF (0805)
C13, C15	100nF (0805)
C14, C16	10μF
C17	1nF (0805)
R1	39Ω (0805)
R2	51Ω (0805)
R3	33kΩ (0805)
R4	150Ω (0805)
R5	680Ω (0805)
U1	ERA1
U2	ADF4007
U3	LM1117
D1	BAT62

5.0

Literature

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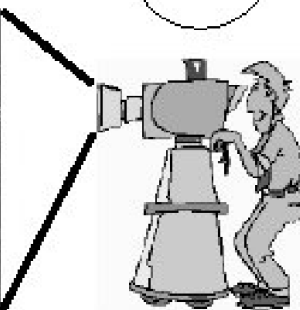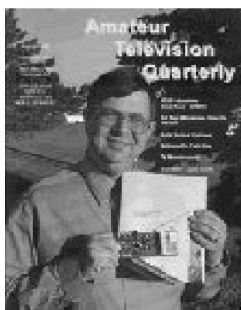
Michael Gabis, Ralf Rudersdorfer

Current digital radio standards similar to FM voice transmission

Part 1

Many organisations, in particular the emergency services, are using modern digital services despite the availability of similar extremely stable FM voice transmission systems. Some experts still have doubts about these services even after decades of development. These become clear by comparing similar FM voice transmission and different digital standards.

A paper based strictly on technical calculations permits a clear comparison

1.

Introduction

Comparisons between different radio technologies are possible from different perspectives. From the available information, based on [9], topics like the maximum possible data rate, call security, or additional digital functions are considered. Some of these are of less importance to some users. For example the data rates attainable with the simplest technologies at present are sufficient for the majority of radio users.

The analogies to similar FM voice transmission refer to the available range and the ability to get trouble free reception with low signal levels. Details of this will be in chapter 3 of the second part of this article.

1.1. Bundled radio

The term bundle radio is often mentioned in connection with digital radio systems, it comes from information in [1] and can be explained as: Digital bundled radio systems are modern radio systems for private and public application and for safety radio applications.

Unlike conventional fixed trunk systems (radio links that are established permanently for each service or user), with bundled radio systems the frequencies are assigned to the individual participants and services dynamically. Thus one can use the "bundle" to increase spectrum efficiency.

1.2. Multiple access; FDMA, TDMA, CDMA

The term of the multiple access defines a set of procedures to allocate the transmission capacity. The different methods for channelling are made possible by multiplexing the signals by frequency or time. There is a substantial difference between these systems and traditional radio systems because they occupy larger frequency ranges as shown in Figs 1 to 3.
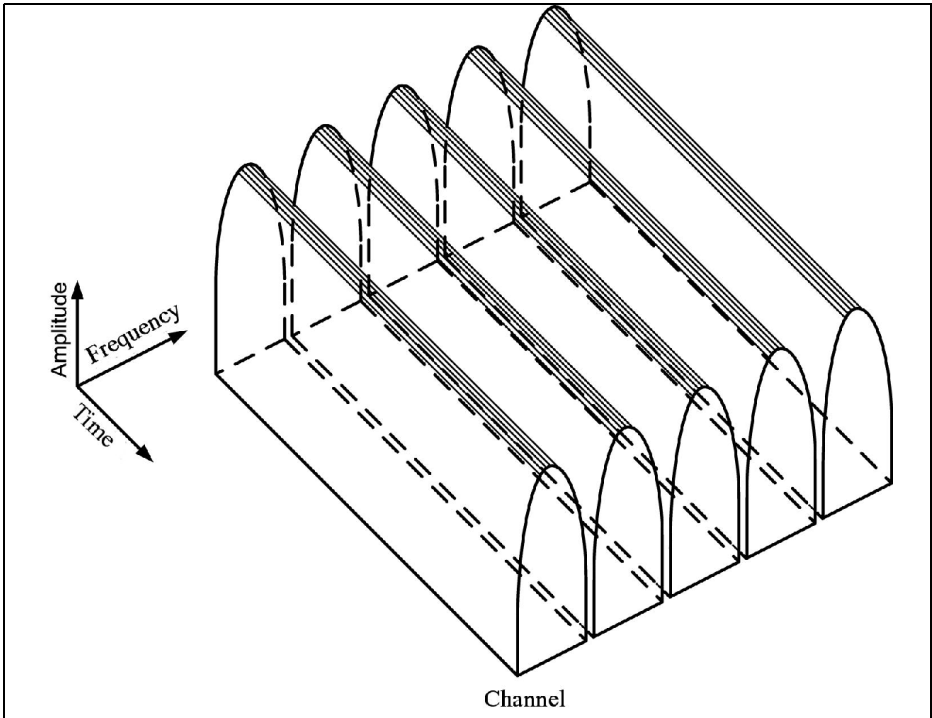
Fig 1: FDMA (Frequency Division Multiple Access): With FM voice transmission each user has their own radio link assigned that is constantly occupied during active radio communication. To serve several users radio channels are placed side by side in a frequency range. This is a classical example of an FDMA system.

2.

Systems

Many digital radio standards have been developed to replace FM voice transmissions, these are described in the following summary by their technical characteristics.

2.1. TETRA

TETRA (Terrestrial Trunked radio) [1] [19] [25] is a digital cellular bundled radio system for speech and data communication. As all bundled radio systems it has a pool of channels with intelligent control of the channel uasge. The channels are assigned dynamically and are potentially available to all participants.

The most important characteristics for TETRA are:

- Small range (in Europe this fits into the existing 25kHz channel system)

- Support for speech and data transmission with different data rates

- Possibility of end-to-end transmission to prevent transmission being overheard
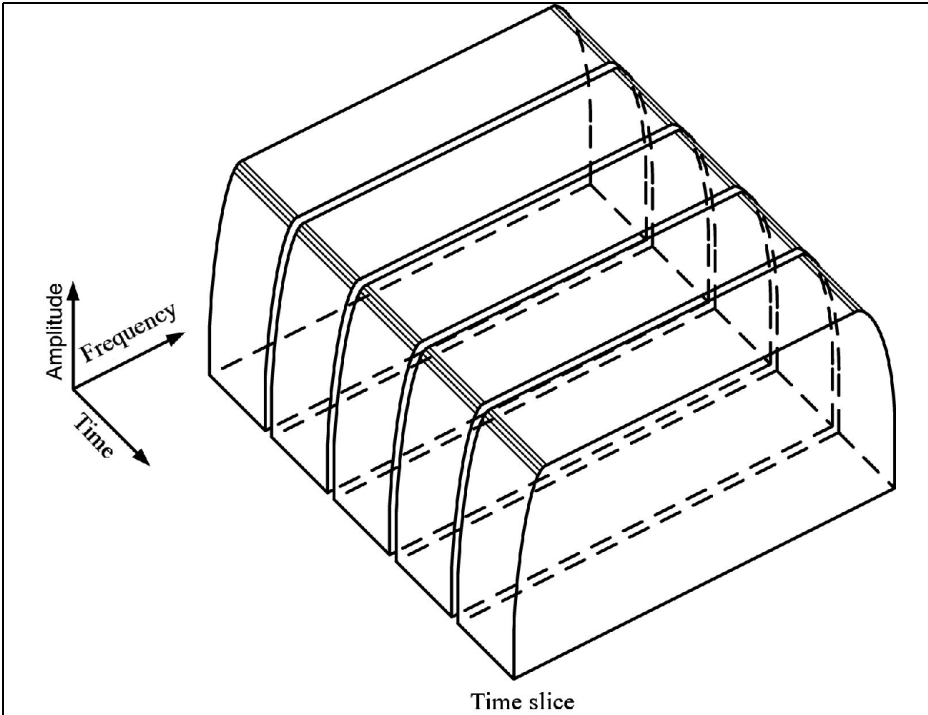
Fig 2: TDMA (Time Division Multiple Access): With TDMA systems several users send and receive channels are divided into time intervals (frequency duplex as for example with GSM) or send and receive channels are the same (time duplex as for example with DECT).

- Fast connection establishment

- Connections in full and half duplex (Push to Talk)

- Individual and group calls

- Broadcast channels (single point to multi-point)

- Support of direct mode in emergencies, the network is not available (e.g. for rescue work in a tunnel)

- Support for Packet and data transmission

TETRA is a TDMA (Time Division Multiple Access) system with four time slots for each carrier (see Fig 2). The first time slot is used for synchronisation and management data. Uplink and downlinks are divided on two separated frequencies. TETRA works with a channel spacing of 25kHz and $\pi/4$ DQPSK (Differential Quaternary Phase Shift Keying) modulation. The channel bit rate is 36kBit/s. It uses CELP speech encoding (Codebook Excited Linear Predictive coding) using 4.8kBit/s.

The available bit rates for each carrier are:

- Unprotected data communication: 7.2, 14.4, 21.6 and 28.2kBit/s

- Error protected data communication: 2.4, 4.8, 7.2, 9.6, 14.4 and 19.2kBit/s

The bit rates from 9.6kBit/s are achieved
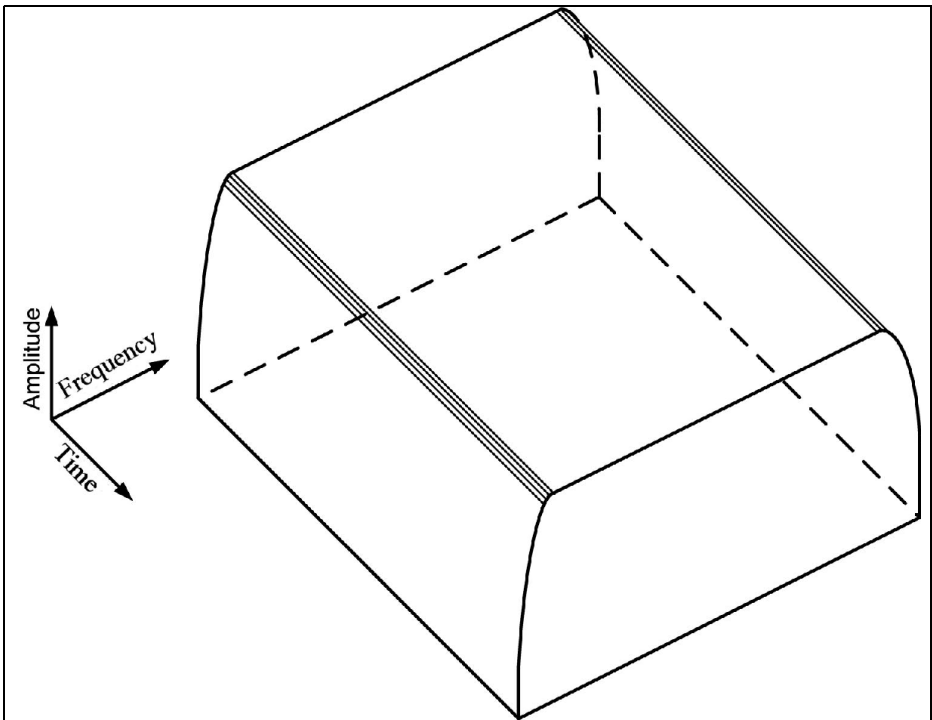
Fig 3: CDMA (Code Division Multiple Access): In radio systems using the CDMA method, many users (up to approximately 128) share a wideband send and receive channel. Users are separated from each other using a "spreading code".

by multiplexing up to 4 time slots. The maximum user speeds in urban areas are 50km/h and in rural areas are 200km/h. The power classes for the base station are from 0.6W to 25W. The hand mobiles have three power classes: 1, 3 and 10W.

2.2. Tetrapol

Tetrapol [2] is like TETRA, a digital cellular bundled radio system for speech and data communication. Tetrapol, unlike TETRA, is not recognised by ETSI (European Telecommunications Standards Institutes), although some countries e.g. Switzerland and France have already used the system.

Tetrapol uses FDMA (Frequency Division Multiple Access). With FDMA (Fig 1), a certain frequency is assigned to each user for a connection. FDMA has a greater range than TDMA under similar conditions and is thus better for large areas. Each cell uses a continuous carrier from the base station as a control channel in order send system data to the mobile devices on the network.

Tetrapol, like TETRA, uses two different frequencies to separate the Uplink and Downlink. The users generally work in the half duplex mode, therefore cannot send and received at the same time.

Tetrapol uses GMSK modulation (Gaussian Minimum Shift Keying). This has the advantage that simple and relatively cheap transmitters can be used. No complex, linear transmitter output stages are required avoiding problems of nonlinear distortion. Also the band usage

and transmit power can be reduced with GMSK. It is not necessary to use linear receivers, economical FM or PM receiver techniques with simple limiter amplifiers can be used.

The advantages of Tetrapol over TETRA are:

- During the same transmission, maximum performance is achieved at up to 50% larger radius than with TETRA. Thus only half as many base stations are required. This advantage is only valid with small traffic volumes, since an individual base station cannot serve as many users.

- The channel spacing is 12.5kHz (not 25kHz as with TETRA) and thus fits well with existing systems.

- Simply too realise

- Devices with TDMA channels like TETRA exhibit larger maximum transmission performance but can cause low frequency audio interference.

The disadvantages of Tetrapol compared to TETRA are:

- Full duplex is not available with Tetrapol, therefore it is only possible with additional cost (Antenna switches)

- Speech and data can be transmitted at the same time with TETRA.

- The data rates of Tetrapol are lower.

- The spectrum efficiency of Tetrapol is smaller.

- Tetrapol is not an ETSI standard.

- TETRA is more flexible and can be used for private applications.

- With TETRA the transmit power of the mobile station is controlled by

the base station to suit current conditions. Interference in the network is reduced and energy saved, which increases the mobile station usage time.

The two modulation systems for TETRA (chapter 2.1) and Tetrapol were compared with one another in [10]. The $\pi/4$DQPSK modulation used by TETRA offers less range but more transmission capacity. GMSK used by Tetrapol represents a compromise between data rate and range and therefore is able to ensure better service even under difficult propagation conditions.

The DQPSK modulation offers far better modulation with lower frequency deviation. However it exhibits insufficient noise performance and interference resistance and thus, compared with GMSK under the same conditions, a higher bit error rate. The optimisation of the deviation ratio of DQPSK modulation is at the expense of receiver sensitivity causing the radio network to suffer.

2.3. DIIS

DIIS (Digital Interchange of Information and Signalling) [11] comes from the ETSI radio standard. It is not competition to TETRA but a logical addition. DIIS was conceived as a single frequency system, not like TETRA a bundled radio system, in order to supply the comparatively small market of lightly populated areas with small traffic densities. TETRA is particularly suited to closely settled areas with middle and high densities of traffic. DIIS is not intended for large systems, but for simple networks (Fig 4) with only one base station or a central relay station and for a direct connection between two mobile devices.

The DIIS standard also describes a re-clocking repeater to increase range. This Repeater can be installed either at an exposed location or in a vehicle in order to extend the range to a telephone
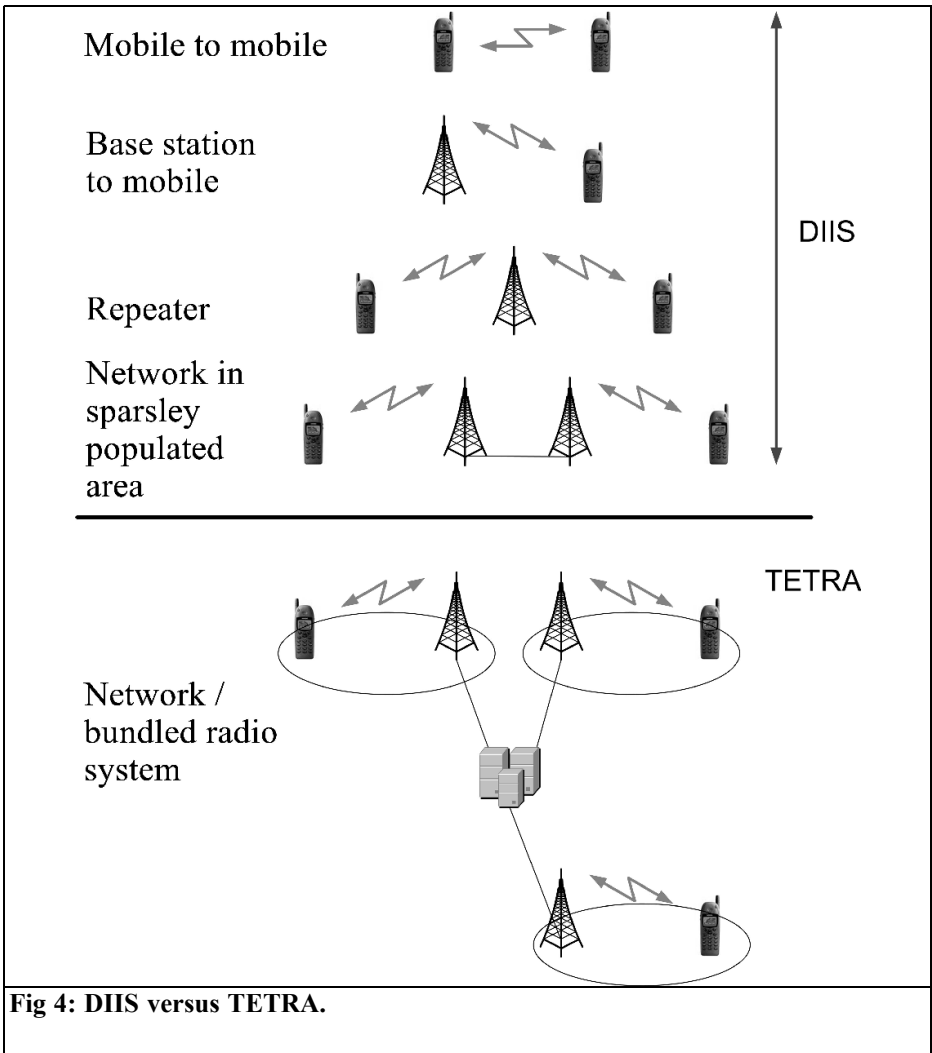
Fig 4: DIIS versus TETRA.

handset in an adjacent building.

The DIIS specification uses 12.5kHz channel spacing in the European operating region. The frequency range used is from 30MHz to 500MHz. 25kHz channel spacing, like TETRA, can be accommodated, in each case two DIIS channels fit in a 25kHz channel. In order to make economical equipment possible it was agreed to use four-phase FSK (Frequency Shift Keying) with constant envelope (4GFSK - Gaussian Frequency Shift Keying). Thus the same advantages apply as for GMSK (see chapter 2.2). This makes it possible to produce a dual mode device that is suitable for the similar systems used as well as DIIS.

The modes of operation for DIIS are simplex, half duplex, duplex and VTDD (Variable Time Division Duplex), where the transmission capacity is assigned to the predominant traffic direction, but
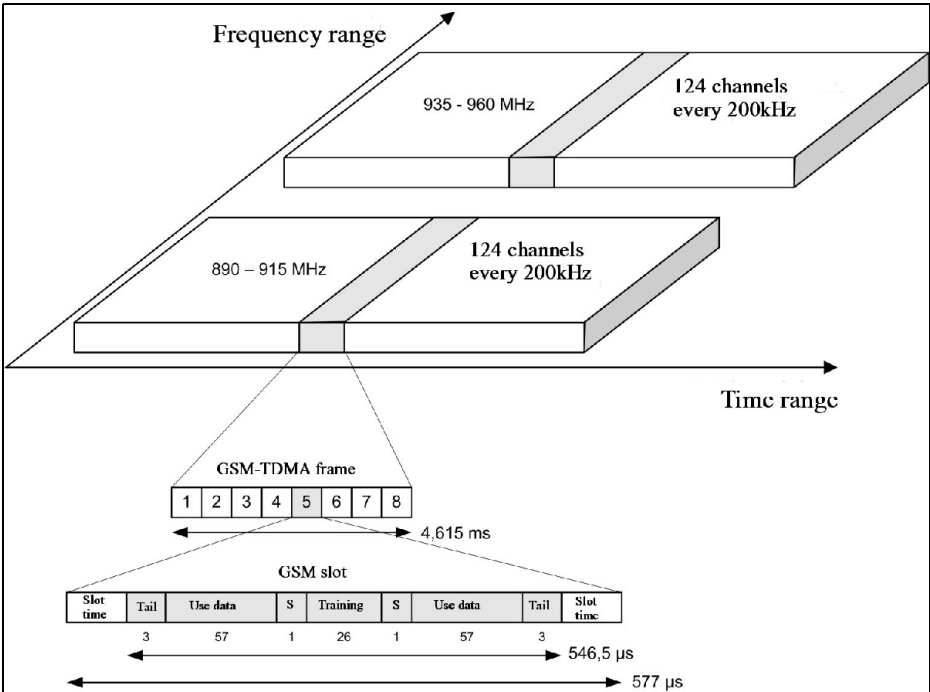
Fig 5: GSM frame structure.

speech in the reverse direction and direction reversal are possible. DIIS offers four fundamental transmission modes: short data such as individual, group and emergency calls or status messages, digital speech transmission, data communication like file transfer and above all a transparent channel for the transmission of arbitrary person-to-person content.

The DIIS project was stopped by ETSI because of patent problems [6].

2.4. GSM

GSM (Global System for Mobile communications) [13], [19], [21], [23], [25] is a digital cellular portable radio standard that has the highest market penetration worldwide.

GSM uses a combination of FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access). With GSM a frequency duplex procedure is used. Uplink and Downlink are separated in frequency by the duplex spacing, whose size depends on the frequency used. The bands used for GSM (850MHz, 900MHz, 1800MHz and 1900MHz) are divided into channels that have a spacing of 200kHz. The signals sent on each of the channels are divided into 8 time slots (TDMA). The TDMA frame duration is 4.616ms. In each time slot a 577µs pulse is transferred (Fig 5).

The modulation is GMSK (Gaussian Minimum Shift Keying) as uses with Tetrapol. The data service EDGE (Enhanced Data rates for GSM Evolution) is a technology used to increase the data rate in GSM networks, 8-PSK (8 Phase Shift Keying) is also used, in order to obtain approximately a three times data rate increase for every pulse.

The base station determines the signal transmission time between mobile and base station and requests the mobile telephone to send the pulses at the correct time. This guarantees that pulse from the mobile telephone arrives at the base station within the intended time slot. This mechanism functions with GSM up to a cell radius of approximately 35km.

After pulse transmission the mobile telephone switches to the receive frequency that is displaced by 45MHz, and receives the backward channel from the base station. Since three time slots transfer Uplink and Downlink channels, a change over switch can be used instead of a duplexer.

The data rate per time slot amounts to 24.7kbit/s this is 22.8kbit/s for the utilisable data (codes and encrypted) and 1.9kbit/s for the user specific control paths (control channels). Because of the channel error coding the actual utilisable data rate is only 13kbit/s in the case of speech data. If a GSM channel is used for data communication, the useable data rate after channel coding is 9.6kbit/s. This transmission mode is called Circuit Switched Data (CSD). Using of a more progressive channel coding 14.4kbit/s is possible. However many block errors can occur so that the download rate can fall, caused by increased errors due to bad radio conditions. These data rates are however low for the most Internet and multi media transmissions, therefore extensions were created such as HSCSD, GPRS and EDGE.

For the speech transmission several codecs (coders/decoders) are specified. A codec defines a procedure that codes and decodes data or signals digitally. The most important codecs used with GSM are fill rate codec (FR), helped rate codec (HR), Enhanced fill rate codec (EFR) and adaptive multi-rate codec (AMR). The codecs supply separate language qualities and separated data rates that affect the number of the people who can telephone over the network. Thus HR can be used if the network is overloaded, with HR used on a time slot two discussions can take place at the same time. The speech quality is however worse.

A direct mode is not specified in the GSM standard. Apart from duplex operation there is also a half duplex service, which is called "Push To Talk" (PTT), the speech is compressed as packets and sent over the package oriented data service GPRS (General Packet Radio Service). PTT has some advantages over a classical radio. With PTT individual users define themselves into groups. Only members of a group can monitor if another member of the group speaks. With a radio everyone can monitor the same frequency even if the contents are intended for a defined person only. Unlike a radio the PTT speech functions works over large areas that are not limited to individual countries due to the roaming facilities of the network carriers. PTT can be received as a group call by mobile phone for a defined group of people that are large distances away. For PTT a PTT server must be installed in the portable radio network [14]. This PTT server controls of correct communication. If the group member A wants to speak, then they press the PTT key. As soon as this happens the PTT server in the portable radio network is checked to see if access is permitted. It could already be speaking to another group member. If the PTT server detects that a voice channel is active by another group member no voice channel and no speech data will transfer from the mobile phone of the group member A into the network. The PTT server retains the member until the PTT key is released. If a member of a group gets the broadcasting right from the server they keep it until the PTT key is released. If a member of the group list is not "ready to receive", then the message for this participant can be buffered in the server so that it can be heard later when the person is ready.

A large disadvantage of PTT is that there

is no guarantee of an immediate connection. Dependent on the contract with the provider it can be delayed by up to six seconds. For a BOS system that would be intolerable.

The network, according to data of the network providers, covers 98% of the population (not the land surface). The network availability, dependent on the network provider, only has an annual average up to 95%. That means that one would have to tolerate a network loss of 18.25 days per year as a customer. There are however extensions to the GSM standard that are described in the following chapters.

2.5. GSM-R

GSM-R (Global System for mobile Communications Rail) [8] [25] is the GSM standard that was adapted by EIRENE (European Integrated Railway radio Enhanced NEtwork) regarding the requirements of the railway network carriers and was to replace the other incompatible national railway communication systems. Some railways carry trans-national traffic and must have up to four incompatible radio systems.

The network architecture of GSM-R is like the public GSM networks. Thus standard components from suppliers can be used. These must be modified for the higher requirements.

Different requirements between GSM-R and GSM according to EIRENE:

- No-break connection up to 500km/h in a tunnel

- C/I (Carrier to Interference) better than 15dB

- Minimum receive level better than -95dBm, with high-speed distances better than -92dBm

- Interruptions by Handover? 300ms

- Line delay of approximately 90ms

- Probability for missed handover with the transition to a strange network under 5%

- 99.9% availability of all services

- Clearly defined priority classes with speech displacement strategies (see Table 1)

- In house services in stations and service buildings

- Guaranteed connection establishment times

Apart from voice communication, like with the "normal" GSM standard (see chapter 2.4) GSM-R also offers group calls, priorities and displacing low priority discussions. The direct mode communication between one or more mobile devices with other networks.

The automatic course control ETCS (European Train Control System) and a transportation logistics were specified in GSM-R.

ETSI released the two frequency bands from 876MHz to 880MHz and 921MHz to 925MHz for GSM-R to prevent conflicts with the public GSM networks.

It is greatly improved over GSM giving better reliability and availability. For increased reliability the BTS (Base Transceiver Station - base station with transmit and receive equipment) will be connected in a ring structure to the BSC (Base Station Controller - controls the sending and receiving resources for the BTS) not in chains as in the public

Table 1: Priority classes for GSM-R.

Class	Call type	Time
1	Emergency calls	<1 sec
2	Broadcast between mobiles	<2 sec
3	Normal person to person communication	<5 sec
4	Low priority users	<10 sec

networks. At particularly critical distances the BTS is an MSC (Mobile Switching Centre) and other network components are duplicated and always form two congruent radio cells, which offer full functionality by themselves. Thus the network of the German railway consists of 7 MSCs, 60 BSCs and 2600 BTSs.

In 95% of the cases of the times in Table 1 must be achieved. For the remaining 5% it may last a maximum of 1.5 times longer.

GSM-R is a portable radio standard that exists only in the railway system at the moment because GSM-R is intended only for the use as a communication system for the railways.

2.6. GSM-BOS

GSM-BOS [5] [22] be based on the GSM standard at 900MHz (see chapter 2.4) and is an extension of this standard. However GSM-BOS is based on a concept of the German arm of the international telecommunications company Vodafone (Vodafone.de).

Unlike GSM-R that has it's own frequency allocation of 2 x 4MHz in the reserved European-wide spectrum, GSM-BOS exists on the commercial GSM network in Germany used by Vodafone.de. GSM-BOS is a further extension of GSM-R (chapter 2.5) with capability characteristics a subset of GSM-R only [5].

Main characteristics of the GSM-BOS concept from Vodafone.de are according to [22]:

Directing centre binding:

Directing centre binding is not used with GSM-R. Vodafone.de offers the linkage between GSM networks and directing centres with the concept of a "Connectivity server". BOS companies can have servers that are located in house a defined by the operator company.

Defined operator company:

- Option for the establishment of an independent operator company

- Safety device of the BOS function over the BOS radio system

- Creation of clear interfaces, in principle a linkage from operator company with the GSM network operator

Direct mode:

- A satisfying solution is between GSM or GSM-R is not possible

- The direct mode is therefore to be realised using TETRA

- Terminals become dual mode devices (GSM BOS / TETRA)

- Numerous final specific characteristics fulfilled by TETRA also apply to GSM BOS

Existing radio net:

- Use of the existing GSM radio network in the range 900MHz

- Radio network adjustment necessary

- Setup of the software on all base stations

- Remove the service deficiencies of the rural areas

- Structure of an overlay network for aircraft

The membership of a GSM-BOS participant in one or more groups is limited to maximum 50 groups. (BOS organizations define approximately 30 groups per BOS unit. A change of the group affiliation is possible in individual cases if required. Group affiliation and communication must be localy dependent. The restriction of a group is to be a maximum of 25 cells, corresponding to an area from 20 to

5000km². The cells must belong to a pre-defined BOS area. Individual participants outside of the BOS area can be merged over other functions into group communication.

With GSM-BOS the first use (mechanism of connection for a group call) and communication in existing group connection must be separated.

95% of first calls take place in less than 2.5 seconds. During a group connection the ready-to-transmit-state is achieved in 0.5 seconds. The mechanism of a group connection usually takes place with entitled members and the directing centre. The time requirements for subsequent communication can be kept by maintaining the connection.

End-to-end encryption is possible with auxiliary modules. A passive alert is not intended in GSM-BOS, thus no alerting is possible for devices. An alternative is an alert by SMS.

The Vodafone.de network is available for 99% of the time per year that means loss is tolerated on 3.65 days per year that is too small for a BOS network. In GSM practice the BTSs and BSCs are equipped with no-break battery emergency power supplies that give continued use for 4 hours. The MSCs are additionally equipped with emergency power generators that make emergency operation possible over several days.

The loss of an MSCs paralyses approximately 90 BTSs attached to it (approximately 220 cells) in the case of Vodafone.de. The effect on the wider network can last up to 24 hours therefore the guaranteed network availability can have drastically negative consequences for the quality of the BOS work. The loss of a cell can lead, depending upon situation, too un-supplied areas, since no complete redundancy is available. The regional consequences can cause local damage. BTS locations are not protected from sabotage, because they are easy to identify and easy to manage.

The maintenance of a connection means that the channel loading is very resource inefficient. There is a risk of time delays for an alert over SMS with very high alarm numbers and no private SMS centre.

Linking similar BOS networks that are missing with GSM-BOS there would be substantial difficulties in co-operation between different BOS organisations. A separation of the infrastructure in BOS and the public network is not possible. According to [5] the GSM-900 frequency band of T-Mobile and Vodafone.de in Germany is too narrow at 11.8MHz to supply over 25 million GSM customers and despite an additionally 5MHz in the GSM-1800 band for a genuine BOS department. However by a better use of UMTS for data communication in the centres of dense development the GSM channel shortage is defused.

A further problem can result from the fact that in Austria all GSM networks, up to A1, could be in the possession of foreign companies affecting national safety interests. The national GSM licenses continue to run; however it is very probable that these licenses are extended.

GSM-BOS developed is still too small according to [5]. The variety of handsets is still too small there is still no vehicle-mounted equipment. Also some countries and organisations have decided to use TETRA or Tetrapol; GSM-BOS will therefore not be used. GSM-BOS originates from the 1st quarter of 2004 and since then has been stable at that specification.

To be continued!

X.

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Alexander Meier, DG6RBP

Digital stepped attenuator for up to 2.4GHz

Step attenuators are used in RF measuring instruments, like signal generators. A simple low cost 51dB stepped attenuator that can be used up to 2.4GHz can be made using modern semiconductor components. It can be done without the need for expensive electromechanical relays.

A stepped attenuator attenuates a high frequency signal, with the attenuation adjustable in defined steps, e.g. 1dB. For a long time attenuators have been developed with resistors (PI or T attenuators) and with electromechanical relays as switches. Today semiconductor attenuators are available, usually they are not so precise but they are small and low priced.

This article shows a stepped attenuator for the frequency range from 10MHz to 2400MHz with an attenuation range from 0 to 51dB. The attenuation is adjustable in steps of 1dB.

1.

Circuit description

The HMC541 and HMC307 integrated stepped attenuators from HITTITE [1] in a very small SMD package were selected. The manufacturers specification shows that the maximum power handling is approximately 100mW.

The circuit diagram of the attenuator is shown in Fig 1. The input signal is fed to the first attenuator, U1 (HMC541), using a coupling capacitor. This is an adjustable attenuator, switched between 0dB with 5V on pin 14 and 10dB with 0V on pin 14. This is followed by a further HMC541 (U2). Thus the attenuation can be selected between 0, 10 and 20 dB. For the finer stages a further integrated attenuator type HMC307 (U3) follows the first two attenuators. The attenuation of this component can be switched using pin 1 to pin 7 between 0, 1, 2, 4, 8 and 16dB. Thus each attenuation value between 0 and 31dB can be set. Together with the two HMC541 attenuators at the input, any attenuation value from 0 to 51dB can be adjusted.

Unfortunately the HMC307 needs a voltage of 0V or -5V on the control inputs, so IC U4 (74HCT04) is used with Zener diodes D3, D5, D7, D9 and D11. This forms a level translator so that the attenuator can be addressed from the outside with 0/5V CMOS or TTL levels. If the cathode of D3 is set to +5V e.g. for the 16dB setting, the Zener diode D3 connected to –5V via resistor R2 gives a voltage of 0V at pin 7 of U4. If the cathode of D3 is set to 0V the Zener diode D3 connected to –5V via resistor R2 gives a voltage of -5V at pin 7 of U4.
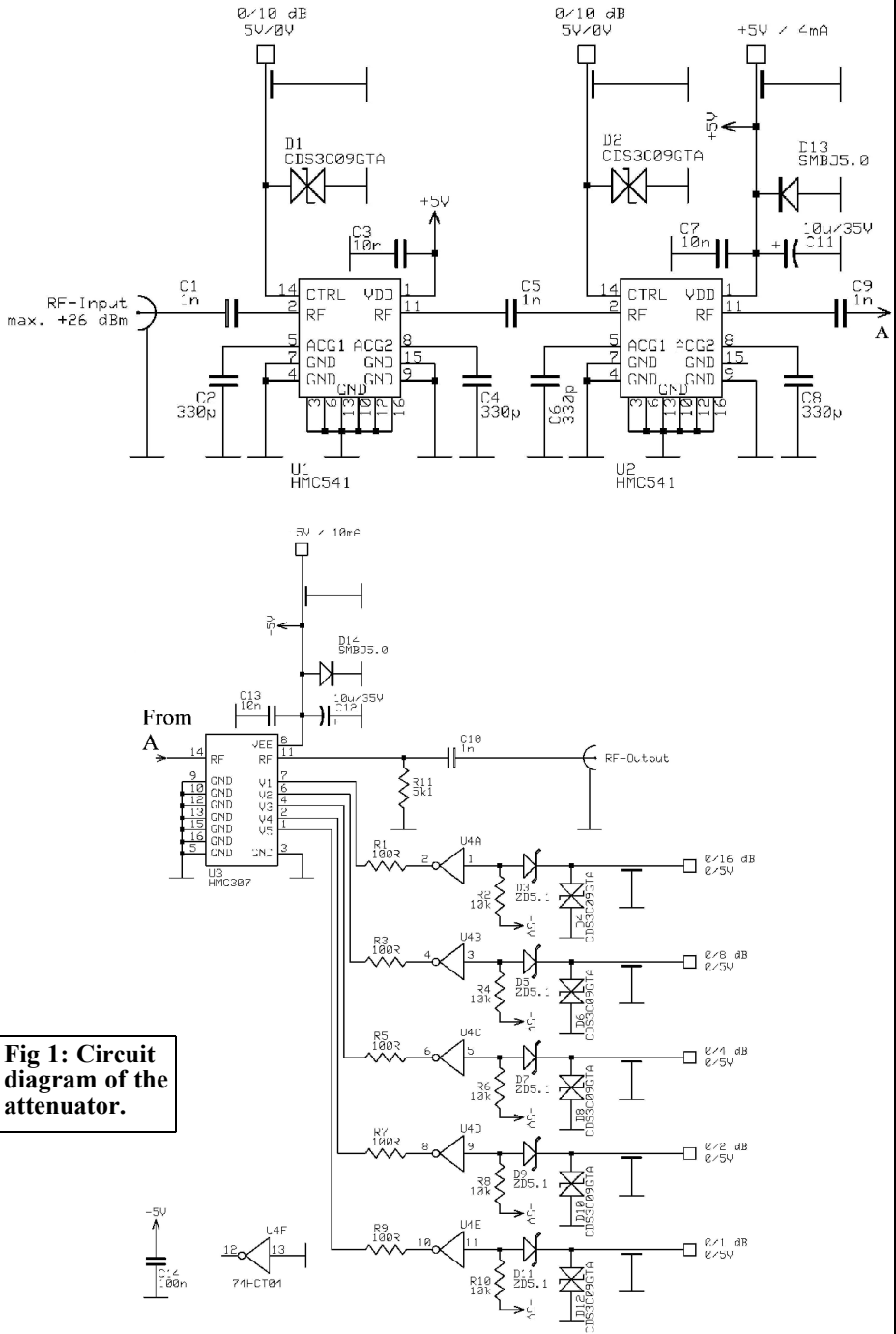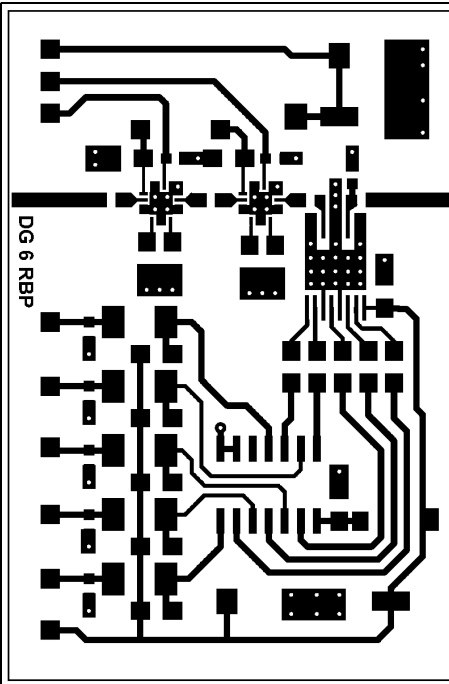
Fig 1: Circuit diagram of the attenuator.

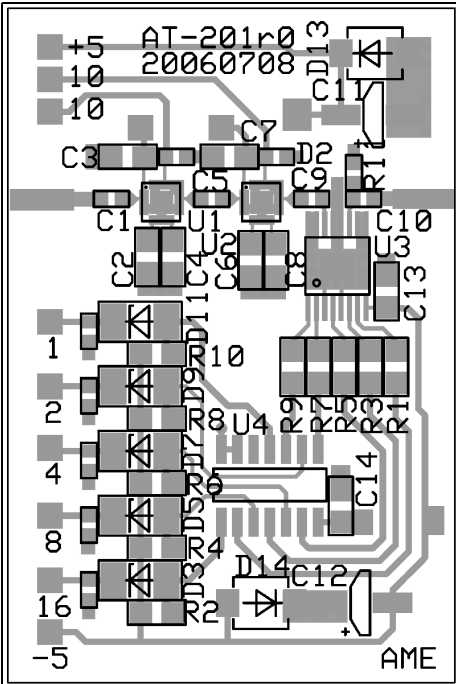**Fig 2: PCB layout for the attenuator. Dimensions 35mm x 53mm.**

Fig 3: Component layout for the attenuator.

Because the inverters of U4 have an operating voltage between 0 and -5V, the CDS3C 09GTA diodes provide ESD protection.

2.

Construction and operation

The PCB layout of the step attenuator is shown in Fig 2, and the component layout in Fig 3. The PCB is 35mm x 53mm with a continuous earth surface on the bottom side.

Assemble attenuators U1 and U2 on the 0.5mm thick PCB first by soldering using a hot air gun. They do not have solder connections that can be soldered with a hand soldering iron. All other compo-

nents can be fitted with a hand soldering iron and lots of SMD experience. To complete construction the printed circuit board is cleaned and bonded into the milled housing with conductive adhesive, e.g. [2]. Fig. 4 shows a picture of a completed sample attenuator.

3.

Parts list

C2, C4	330pF, 0603
C1, C5, C9, C10	1nF, 0603
C3, C7, C13	10nF, 0805
C14	100nF, 0805
C11, C12	10µF/35V, SMD Electrolytic
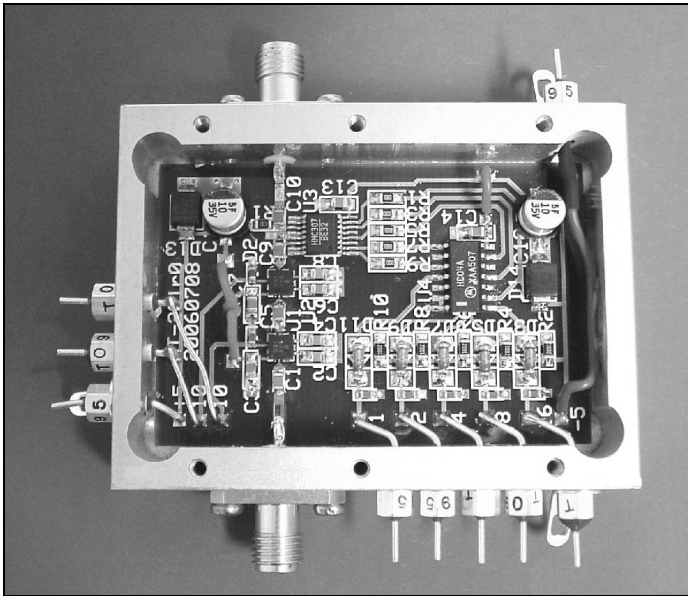
Fig 4: Picture of a completed attenuator.

9	1nF Screw fitting feedthrough capacitor
R1, R3, R5, R7, R9	100Ω, 0805
R11	5.1kΩ, 0603
R2, R4, R6, R8, R10	10kΩ, 0805
U1, U2	HMC541 LP4
U3	HMC307 QS16G
U4	74HCT04

D3, D5, D7, D9, D11	Zener diode 5.1V
D1-D2, D4, D6, D8, D10, D12	CDS3C09GTA
D13, D14	SMBJ5A
1	PCB DG6RBP
1	Milled aluminium housings
2	SMA Flanged connector
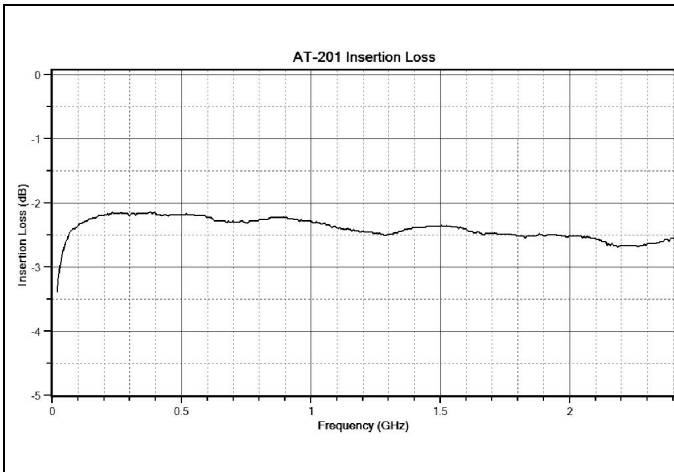
Fig 5: The insertion loss of the attenuator versus frequency.
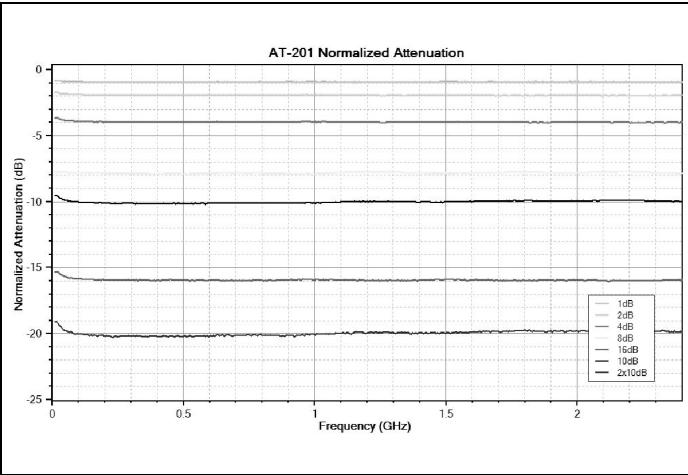
Fig 6: The normalised attenuation for the attenuation steps versus frequency.

4.

Measurement results

The insertion loss of the attenuator that increases with high frequencies is approximately 3dB is shown in Fig 5. The normalised attenuation, i.e. the attenuation above the insertion loss, is shown for the individual steps in Fig 6. The accurate and flat attenuation is remarkable for the low priced components! Fig 7 shows the attenuation error (deviation from the target attenuation). The return loss at input and output is shown at an attenua-

tion of 20dB in Fig 8 and 9.

It should be noted that the lower frequency limit is specified by the coupling capacitor used. From the results of measurement the attenuator can be used down to 10 or 20MHz with the capacitor chosen. With a larger capacitor, e.g. 100nF, the limit can be shifted down to a few hundred kHz! However capacitors with larger capacity are inclined to give problems in the upper frequency range. If necessary a special wideband high frequency capacitor should be used.
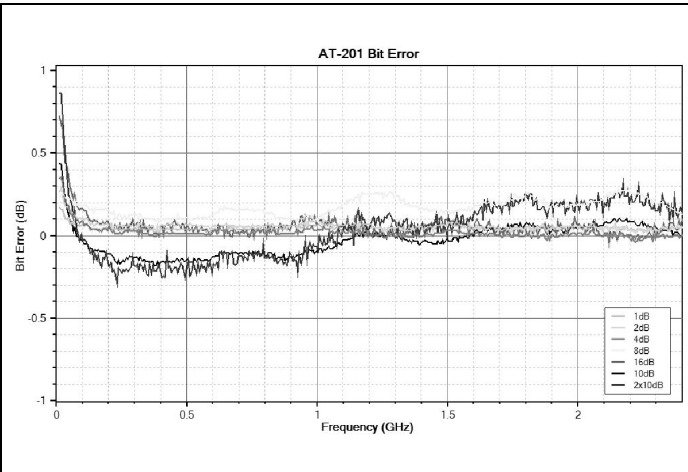
Fig 7: Attenuation error versus frequency.
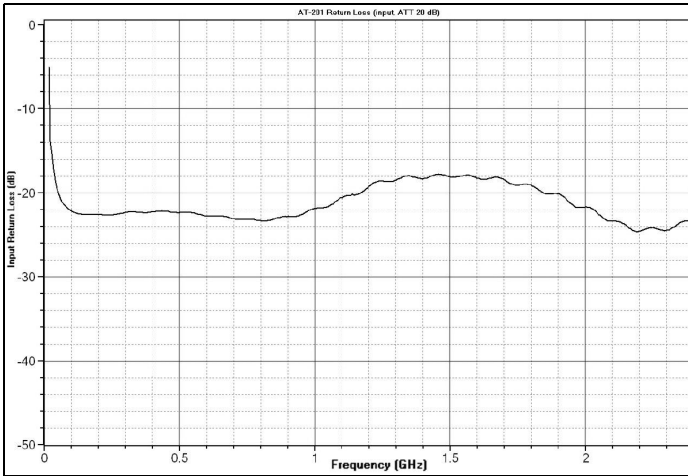
Fig 8: The return loss at the input of the attenuator set to 20dB.

5.

Literature

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http://www.hittite.com/

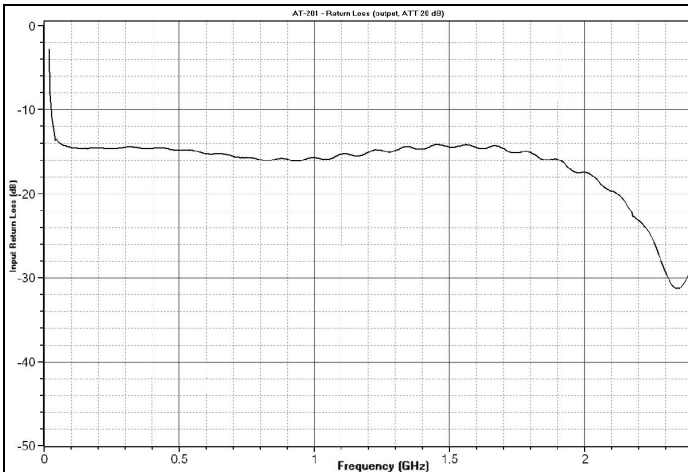[2] Conductive adhesive, RS-496265, RS Components, http://www.rs components.com/index.html

Fig 9: The return loss at the output of the attenuator set to 20dB.

Jochen Jirmann, DB1NV

From the bit to multi-carrier modulation - basics of digital modulation techniques

From a lecture at the VHF conference in Weinheim/Bensheim 2006

Digital modulation techniques have been used in radio engineering for a long time. Together with the use of signal processing it can combine the advantages of digital transmission at low cost. The following overview of digital modulation techniques in the time and frequency domain gives an insight into modern multi-carrier techniques. As an example Digital Radio Mondiale (DRM) is digital short wave broadcasting.

1.

Basic techniques of digital transmission

How does the bit become the RF carrier? The three standard practices of amplitude, frequency and phase modulation can be transferred directly to the digital world. In the simplest form modulation methods that contain only one bit are used, e.g. radio telegraphy using two frequencies for zero and one. If the transmission path is errors free a modulation method can contain more of than two conditions and transfer more than one bit; there are communication techniques with 16 frequencies meaning that the symbol contains 4 bits.

Amplitude Shift Keying (ASK):

The simplest form of amplitude modulation is pulsing the carrier for telegraphy. Since the zero condition cannot be differentiated from an interrupted connection, in practice two amplitude values are used: During transmission of DCF77 for example, 100% and 25% amplitude are used.

Advantages:

- Modulation spectrum is only upward and symmetrical to the carrier frequency
- Modulation can take place somewhere between the oscillator and the antenna
- Amplitude can be directly measured at the receiver

Disadvantages:

- Amplitude errors on the transmission (fluctuations in level, malfunctions) produce errors
- Frequency Shift Keying (FSK): The modulation method uses different frequencies, e.g. RTTY and packet radio use two frequencies for zero and one. It can be interpret either as two phase amplitude modulated channels or as frequency modulation with a non-existent centre frequency with a deviation of ΔF. If the spacing of
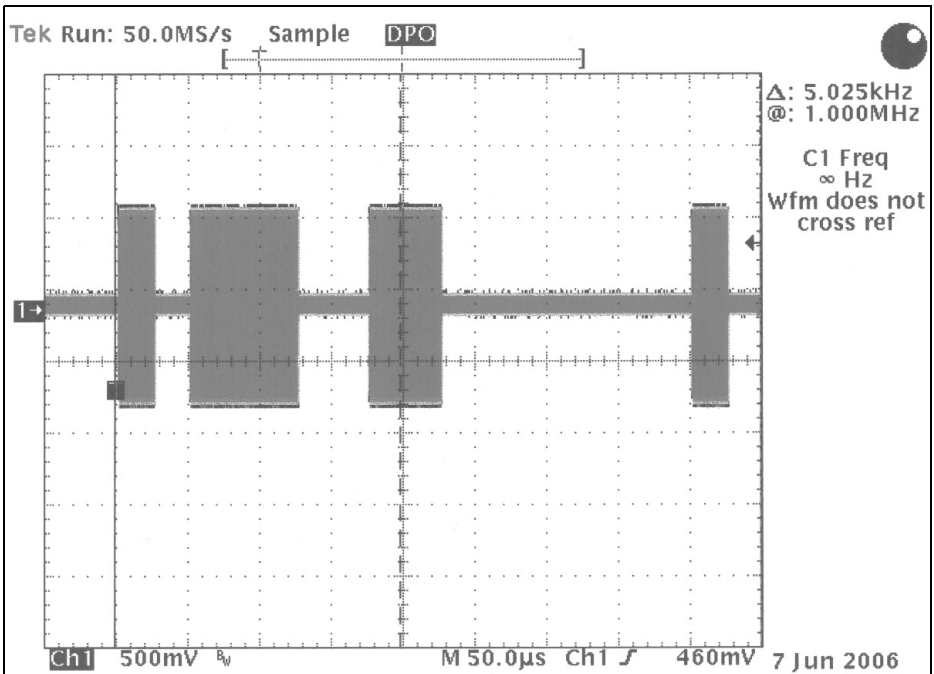
Fig 1: An amplitude modulated 10MHz signal.

the two frequencies is equal to half the data rate, then it is called Minimum Shift Keying (MSK). This is the standard modulation for the GSM mobile phone system.

Advantages:

- Amplitude does not contain any information therefore it is interference proof
- No linear transmitter amplifiers or linear receivers necessary
- Frequency can be directly measured at the receiver

Disadvantages:

- The frequency modulated carrier is theoretically infinitely wide, broader than AM (B ≈ 2Δ + 2f$_{mod}$)
- Modulation requires modulating the oscillator thus worse frequency stability

Phase Shift Keying (PSK):

Using mathematics it can be shown that frequency and phase modulation are very similar and can be converted to one another using suitable filters. The most common method uses two-phase shift keying (0/180°, Binary Phase Shift Keying) and a four-phase shift keying (0/90/180/270°, Quadrature Phase Shift Keying). The two-phase shift keying can be treated as a special case of the amplitude modulation where the carrier frequency is first multiplied by a factor +1 and then by a factor -1. The four-phase shift keying can be considered as two BPSK signals with carriers that are phase shifted by 90°. It can be shown mathematically that these two equivalent carriers do not affect each other and they can be used for BPSK or AM and modulated with different

89

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RBW     1 kHz    RF Att    40 dB
Ref Lvl                  VBW     1 kHz
10 dBm                   SWT     20 s    Unit      dBm
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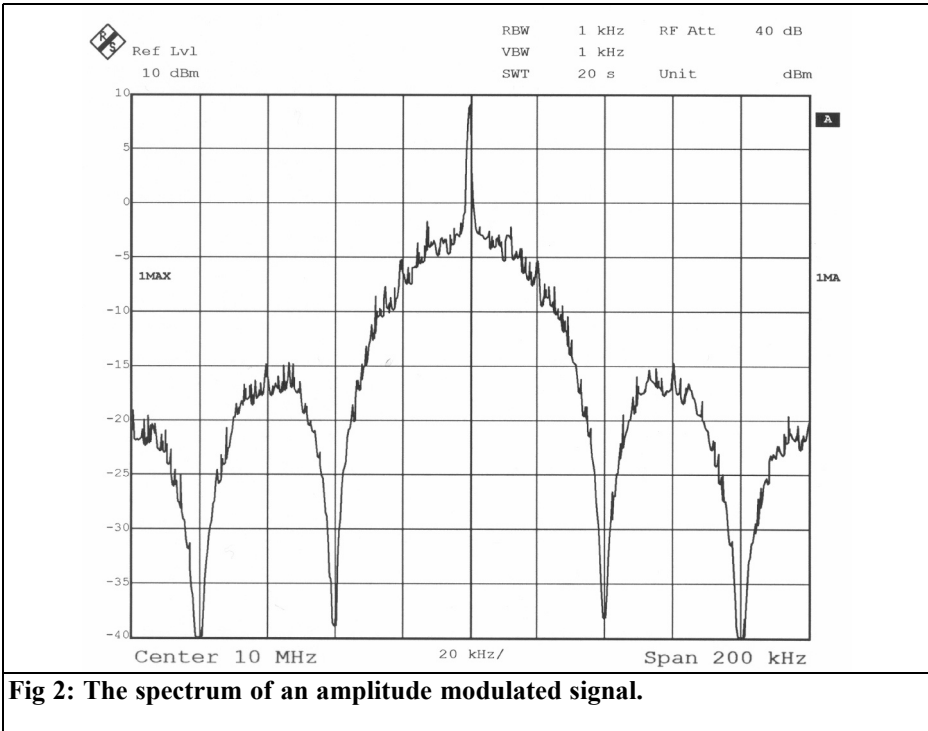
Fig 2: The spectrum of an amplitude modulated signal.

information.

Advantages:

- The phase modulator comes after the oscillator
- Amplitude does not contain any information therefore it is interference proof
- No linear transmitter amplifiers or linear receivers necessary

Disadvantages:

- Phase cannot be directly measured at the receiver, only phase changes
- The frequency spectrum is wider than the comparable AM or FM signals

Combined methods :

Quadrature Amplitude Modulation (QAM): If a transmit path is linear and has a good signal-to-noise ratio, then the data rate can be increased by a combination of amplitude and phase modulation: The amplitude and phase of the carrier is changed at the same time in small steps. Quadrature amplitude modulation accommodates 4 to 15 bits. QAM with 16 states (4 bits) and 64 states (6 bits) is in common use.

The main application for higher QAM methods with 1024 to 32768 states are modems and DSL technologies on fixed line connections.

Advantages:

- Best utilisation of the transmit path in terms of bits/Hz .

Disadvantages:

- Good signal-to-noise ratio necessary
- Linear transmit path from the transmitter to the receiver necessary
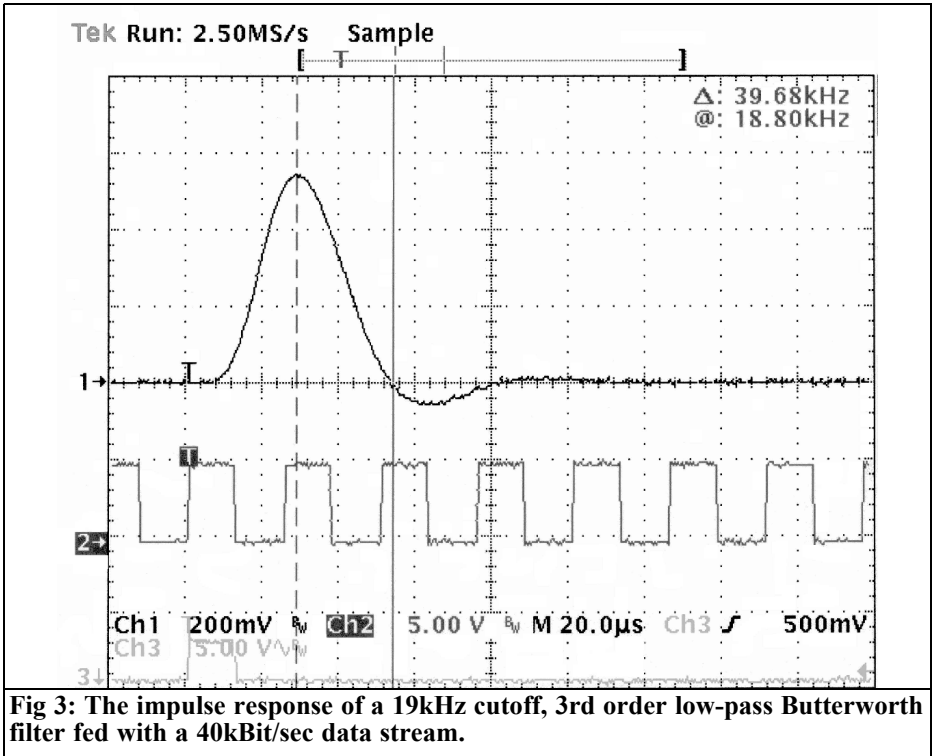
Fig 3: The impulse response of a 19kHz cutoff, 3rd order low-pass Butterworth filter fed with a 40kBit/sec data stream.

2.

Modulation in the time domain and frequency domain and filtering of the data signal

It is known that switching the carrier of a telegraph transmitter produces clicking disturbances in neighbouring radio links. A low-pass filter in the transmitter solves the problem if the modulator and the following transmit amplifier are linear. How is the low-pass designed? Harry Nyquist found the answer years ago with the investigation of machine produced telegraph signals:

The most unfavourable case is the bit pattern (01010101….) corresponding to a symmetrical square wave pulse. A data stream of 1kBit/sec represents a square wave pulse with a frequency of 500Hz

If the base frequency of the square wave is fitted to the transmission path the harmonics are filtered out. The data stream then becomes a sine wave and it is difficult to find the centre of the bits, which is a problem for clock regeneration.

Broadband modulation:

A digital data stream has a very fast rise time (74HC logic: Rise time < 10nS), its spectrum extends far beyond data rate. An un-filtered data signal should not be fed to a modulator because it produces broadband modulation that makes neighbouring radio links useless. The same thing happens if an SSB transmitter is over driven producing a square signal feeding the output stage, some contest stations can be heard +/- 300kHz and
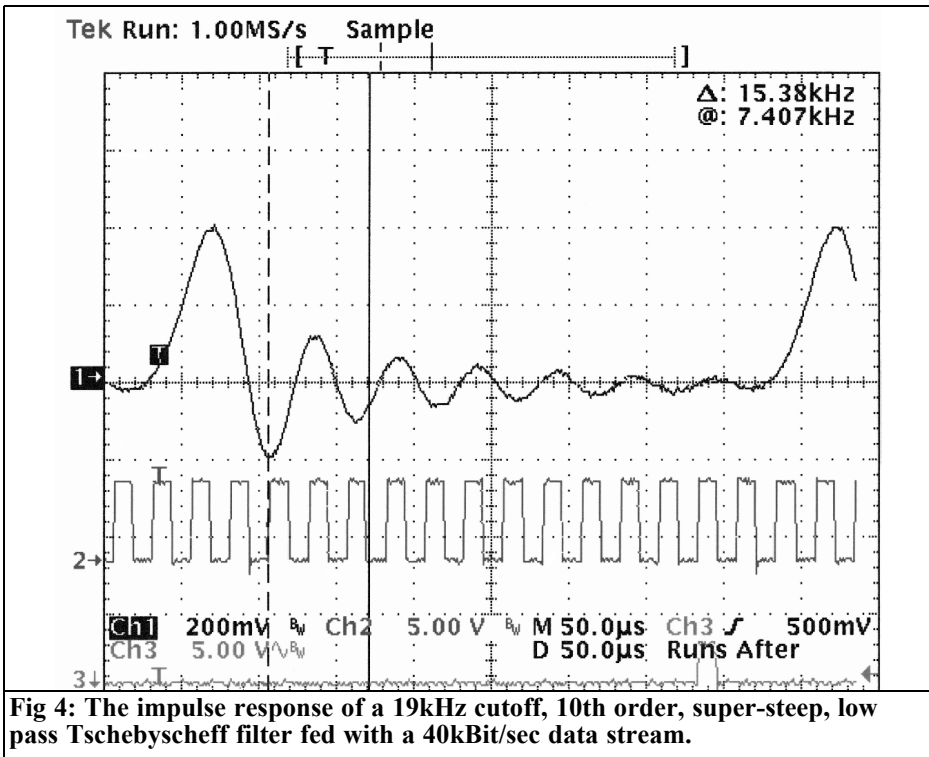
Fig 4: The impulse response of a 19kHz cutoff, 10th order, super-steep, low pass Tschebyscheff filter fed with a 40kBit/sec data stream.

that is not because of a bad receiver!

An amplitude modulator is used for the following examples. A diode ring mixer is used as an AM modulator for a 10MHz carrier. The data stream has a data rate of 40kBit/sec and a 32767 ($2^{15}-1$) bit pseudo random generator is used to represent the data.

The modulated signal is shown in the time domain in Fig 1, the bit length is 25µsec from the 40kBit/sec data rate. The associated spectrum is shown in Fig 2; the carrier frequency is in the centre and the sidebands extend 200kHz to the left and right. For those interested in the mathematics: the amplitude of the sidebands follow (sin x)/x function. With such a signal the neighbouring radio links would be substantial disturbed. The modulation signal must be filtered in a suitable way! Subjectively it is assumed that

with reduced rise time of the data signal the range occupied becomes smaller. At first sight a sharp low-pass filter is the solution, but this is discussed further.

Correct filtering of the modulation signal: Most IF bandpass filters in amateur radio equipment are optimised for a rectangular transmission curve, because the Shape Factor is an important advertising feature but most special CW filters under 250Hz ring and are hardly useful. A CW signal only occupies a few Hz so why doesn't it fit in a 100Hz filter? Then there are the strange transmission curves of the IF bandpass filters in a spectrum analyser.

This is where filter theory helps:

If a low-pass filter is fed with a short rectangular voltage pulse or a short RF
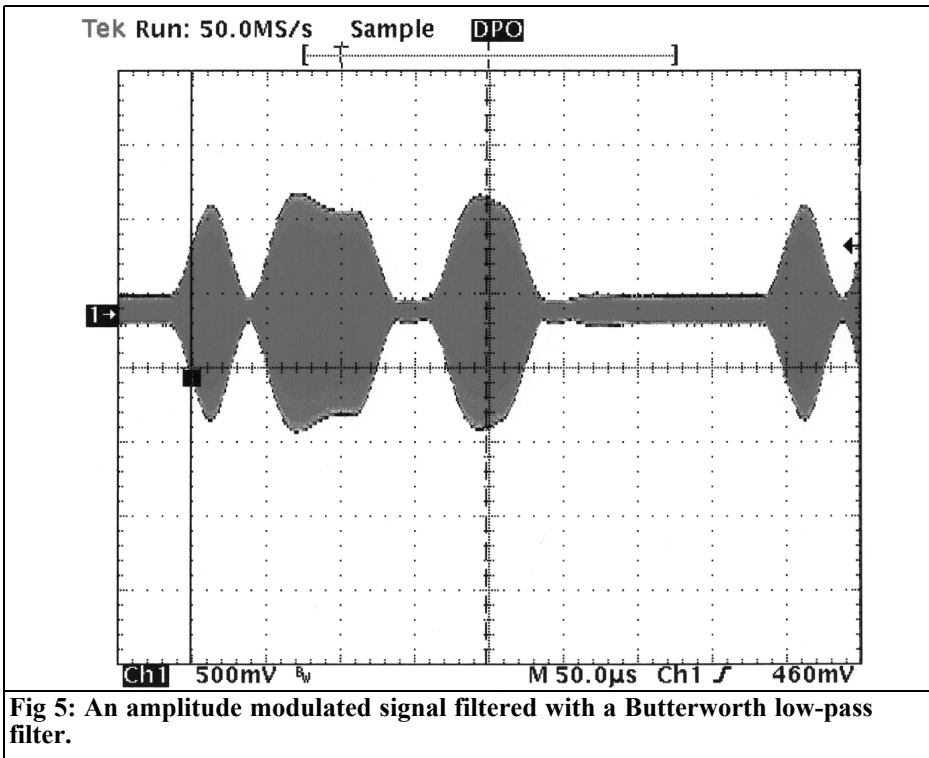
Fig 5: An amplitude modulated signal filtered with a Butterworth low-pass filter.

pulse at the centre frequency of a bandpass filter, then the output is not only a reduced version of the original input but also echoes that are the ringing of the CW filter. The "better" the filter the more echoes can be seen. The impulse response of a 19kHz cutoff, 3rd order low-pass Butterworth filter fed with a 40kBit/sec data stream is shown in Fig 3. The second trace is the clock. The pulse has been beautifully "rounded":

One bit time later the pulse response crosses zero, which means that neighbouring bits in the bit stream are not affected

A negative echo of the origin pulse can be seen, its amplitude is approximately 10 times smaller than the first pulse.

Fig 4 shows a 10th order, super-steep, low pass Tschebyscheff filter with an almost rectangular transmission curve.

The data rate is again 40kBit/sec and the cutoff frequency 19kHz. 12 echoes of the origin pulse can be seen fading away sinusoidally so this filter is not useful. The following requirements result for filtering digital signals:

- A low pass filter with a cutoff frequency of half the data rate can be used to filter digital signals and leave the bits recognisable.

- Low-pass filters must have a gradual transition into the cutoff area so that the filter does not ring. Theoretically the optimal solutions are Gaussian filters (as used for IF bandpass filters in spectrum analysers) and Cosine roll off filters with a cosine shaped filter curve.

- The 3rd order Butterworth low pass filter represents a good approximation.

- By small variations to the filter

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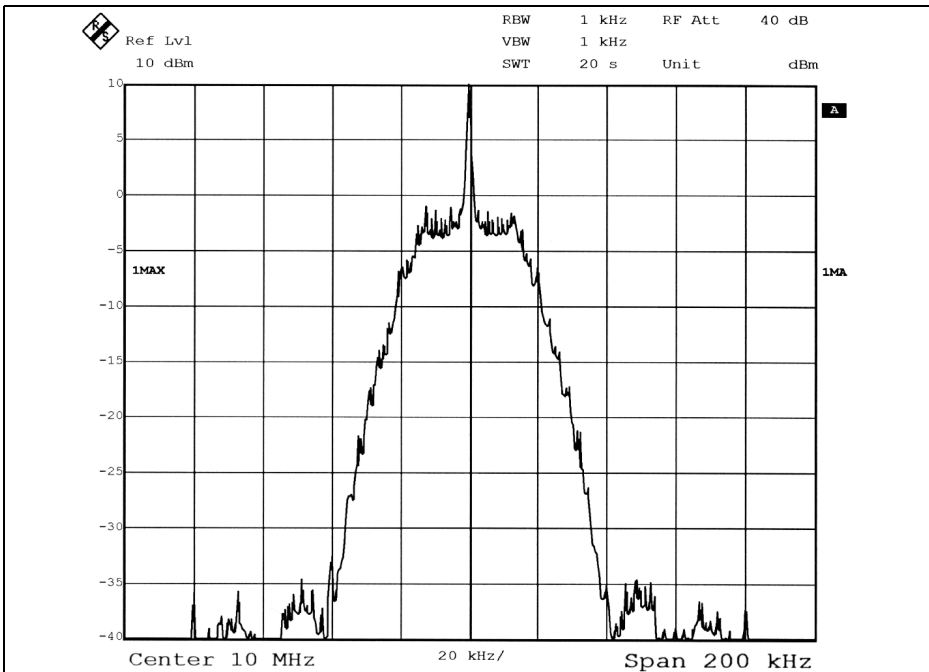
Fig 6: The spectrum of an amplitude modulates signal filtered with a Butterworth low-pass filter.

cutoff frequency the pulse response of the filter can be designed to make the zero cross over in the centre of the following bit so that neighbouring bits affect each other as little as possible.

The advantage of the last point can only be achieved if the bit timing is recovered in the correct phase at the receiver and the bit stream is scanned in the centre of the bit timing. This highlights two additional tasks: The transmitter must send sufficient bit changes independently of the bit stream to ensure that the bit timing can be recovered. The receiver must be able to recover the bit timing, usually using a PLL circuit.

The success of filtering with a Butterworth filter is show in Fig 5 in the time domain and Fig 6 in the frequency domain. The formerly rectangular RF envelope is rounded and the power density at more than 40kHz from the

carrier is practically zero.

Disturbed transmission paths:

Digital transmission techniques were introduced with the goals of improving quality and of reducing the equipment cost. To start with digital transmission techniques were concerned with the increase of the bit rates into the Gigabit region so that the gigantic capacity of fibre optic cable could be used. That can be achieved with carefully planned transmission paths that have a good, well-behaved and smooth frequency response and low noise. These conditions are fulfilled by cable but not by radio paths.

- On long cable runs the characteristic impedance jumps if the connections are not implemented correctly causing humps in the frequency response.

- Multi-path propagation in a hop
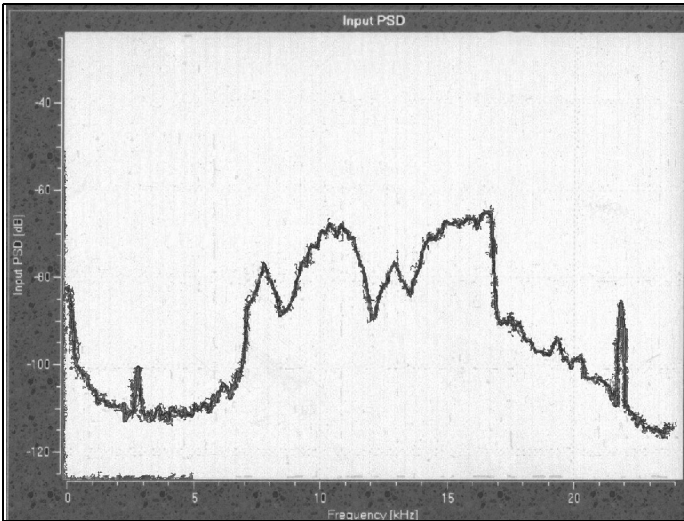
Fig 7: Frequency responses of a DRM transmission on short wave

produces sharp "holes" in the frequency response caused by interference

- Foreign transmissions disturb both cable runs (cross talk from other cable cores or unsatisfactory shielding) and radio links.
- The frequency response of DRM reception taken with strongly disturbed frequency is shown in Fig 7 and Fig 8.

The following is applicable:

- A frequency response equaliser gives good results so that the frequency response is not too uneven.
- Some radio systems use automatic channel selection and look a good radio link
- Using frequency diversity technology the information is transmitted on two frequencies in
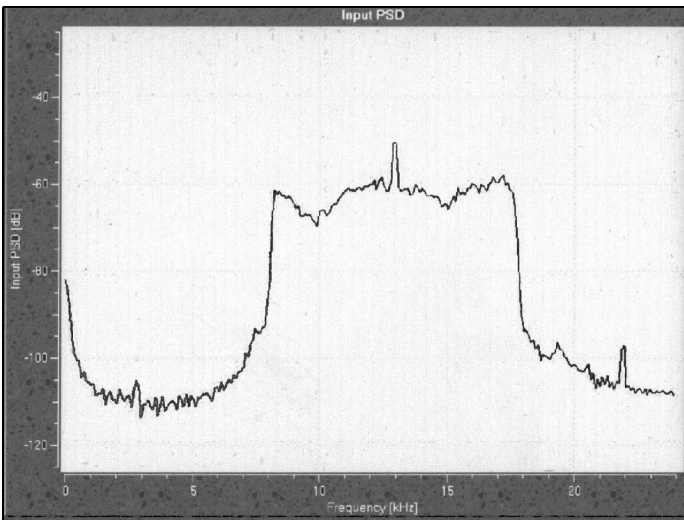
Fig 8: Frequency responses of a DRM transmission on short wave
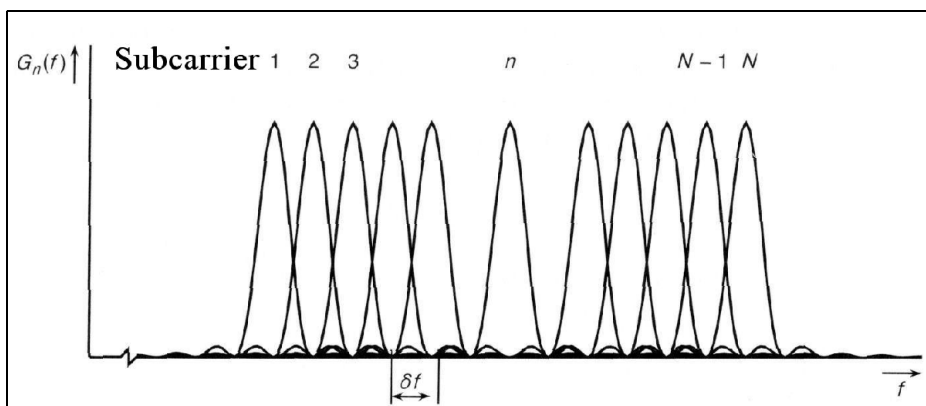
Fig 9: Carriers for an orthogonal frequency multiplexed system (OFDM).

the hope that one is good.

Area diversity uses a second receiving antenna shifted by some wavelengths that often supplies unimpaired reception during multi-path propagation.

A difficult radio link in California has used double frequency diversity and quadruple area diversity for some years.

Advantages of multi-carrier modulation:

The frequency diversity method can be used with more consistency. Before the digital age telephone calls were converted using frequency-multiplexing equipment into single sideband modulation; the method meant that the calls could be transmitted using both cable and radio (radio relay link or satellite communication). If a sub channel was disrupted it was not used. With a disrupted channel unused only the transmission rate was affected and the connection was not broken, the same applies to a digital transmission.

This advantage has been rediscovered with the availability of special signal processors thus overcoming the arguments against frequency division multiplexing. The modulators and filters for each sub channel can be realised

digitally using cheap signal processors. There are many cable and radio systems using digital frequency multiplexing equipment:

- ADSL technology (Asymmetric Digital Subscriber Line) uses 4kHz wide sub channels with 4.3125 kHz spacing
- DAB (Digital Audio Broadcasting) uses 1536 sub channels in a 1.5MHz spread spectrum
- DVB-T (Digital Video Broadcasting - Terestrial) uses 2048 or 8192 sub channels in one 7MHz wide Television channel
- DRM (Digital Radio Mondiale) uses the 9kHz wide AM radio channels with 40 to 110Hz(!) spread sub channels.

Even the portable radio planners think after the failure of UMTS and spreading spectrum modulation multi-carrier modulation (3G) that this is the 4th generation portable radio system.

It must not be forgotten that a multi-carrier modulation system has a considerable administration overhead. With a two-way system users can still operate with the loss of a single channel of the distributed channels. Broadcast systems send enough redundant
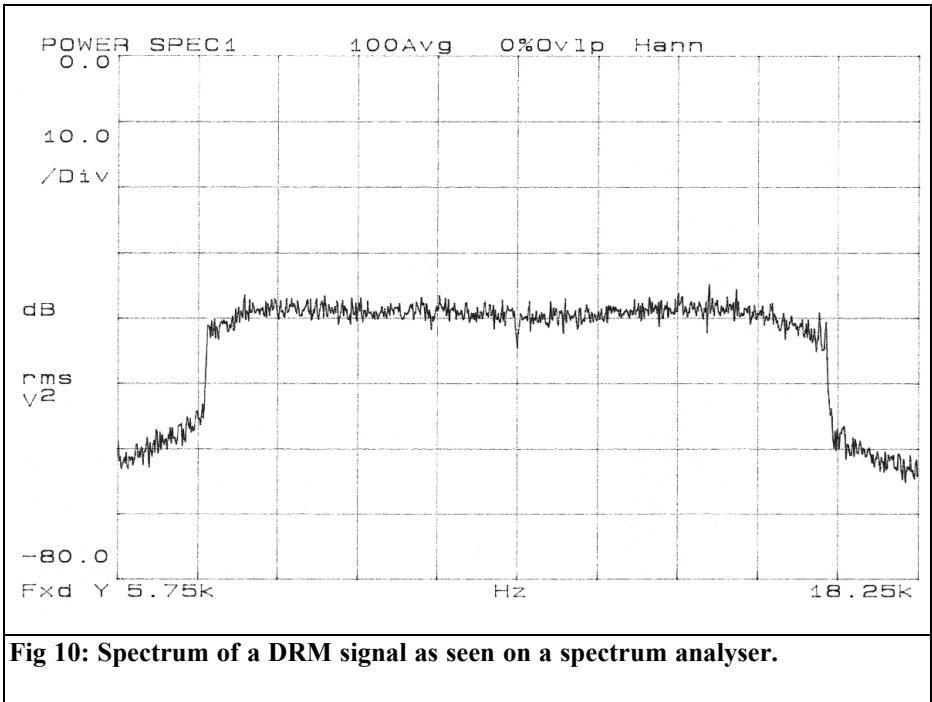
Fig 10: Spectrum of a DRM signal as seen on a spectrum analyser.

information so that it does not present a problem if a certain portions of the channels are not usable.

A recognised disadvantage of multi-carrier systems is the long synchronisation time: a DSL modem does not need many seconds to synchronise, depending upon line quality, a transmitter search can be used for digital television broadcasts. The developments to a DRM similar amateur radio procedure run however!

Summary of the pros and cons of multi-carrier systems:

Advantages:

- Well suited to bad transmission paths with poor frequency response or sharp breaks
- The frequency response only needs to be good in the sub channel
- Data with a low rate is transferred in the sub channel. Thus the

transmission becomes insensitive to multi-path propagation. The requirement is that the transit time difference between the multi path waves at the receiver must be smaller than the symbol length

- Individual sub channels can fail completely during transmission

Disadvantages:

- The modulation is generated with considerable amounts of digital signal processors
- Pilot channels must be inserted for recovery
- The synchronisation procedure is long therefore it is suitable for permanent connections

Practical realization: DMT and OFDM:

The term Digital Multi-carrier Modulation (DMT) is self-descriptive.

The term Orthogonal Frequency Division Multiplex (OFDM) is also used in connection with multi-carrier modulation. Orthogonal means right-angled, but why is this used for a transmission technique? Sine and cosine waves are orthogonal for the same frequency, if they are multiplied together then the dc component is zero. That has been used for many years in quadrature amplitude modulation for PAL colour television transmissions to transfer two channels on a carrier.

The frequency spacing of the sub carriers for a multi-carrier modulation can be chosen freely as long as the spectra do not overlap themselves. There are carrier spacings where the mutual disturbance becomes minimal thus saving on filtering.

Looking again at Fig 2: Although the data signal is not filtered, the spectrum falls to zero symmetrically around the carrier at a spacing of the bit rate. Therefore it is best to select the frequency spacing of the sub carriers at integer multiples of the symbol rate. The first case (standard OFDM) does not give the closest packing of the sub carriers but theoretically the sub channels do interfere. This is because the information is carried in the range of the carrier frequency plus/minus half the symbol rate as shown in Fig 9 from [1]. This cannot be seen on a spectrum analyser; only the rectangular form of the whole spectrum can be seen as shown in Fig 10.

3.

Digitally Radio Mondiale - current state

In the last few years some digital broadcast and television systems have been introduced, whose use for the ordinary consumer is either doubtful or who does not fulfil expectations created by advertising:

- Digital Satellite Radio (DSR) failed after 5 years due of lack of participants!
- Digital audio Broadcasting (DAB) has been operating for years in the general market and should replace VHF FM broadcasts. The quality loss compared to VHF FM is not great but it is doubtful if the population will accept 100 million worthless radios in Germany alone even after a long period of use and low priced receivers. It is not clear what the thoughts of DAB are in other countries. (In the UK it is even more troublesome because the BBC standard for DAB is not the same as the European standard and is due to be harmonised with even more useless receivers – Andy)
- Digital Video Broadcasting (DVB) was publicised to have better image quality and in addition still more programs. These are (usually) of the lowest technical quality (data rate under 2MBit/sec) and squeezed into the transmission paths. With modern large screen televisions one the bad image quality can be seen showing "dancing pixels".
- DVB-T has the advertising slogan of television for all, many programs using a Yagi antenns..
- DVB-H (television on the mobile phone), it is doubtful if this will become a market success.
- Now DRM (Digital Radio Mondiale) is about to digitise the medium and short wave broadcast bands. Is a market success to be expected here? No mass market, but an interesting addition: a clear jump in audio quality (almost VHF FM quality) compared to AM broadcasts and at the same time worldwide reception with only telescopic antenna an no additional infrastructure.
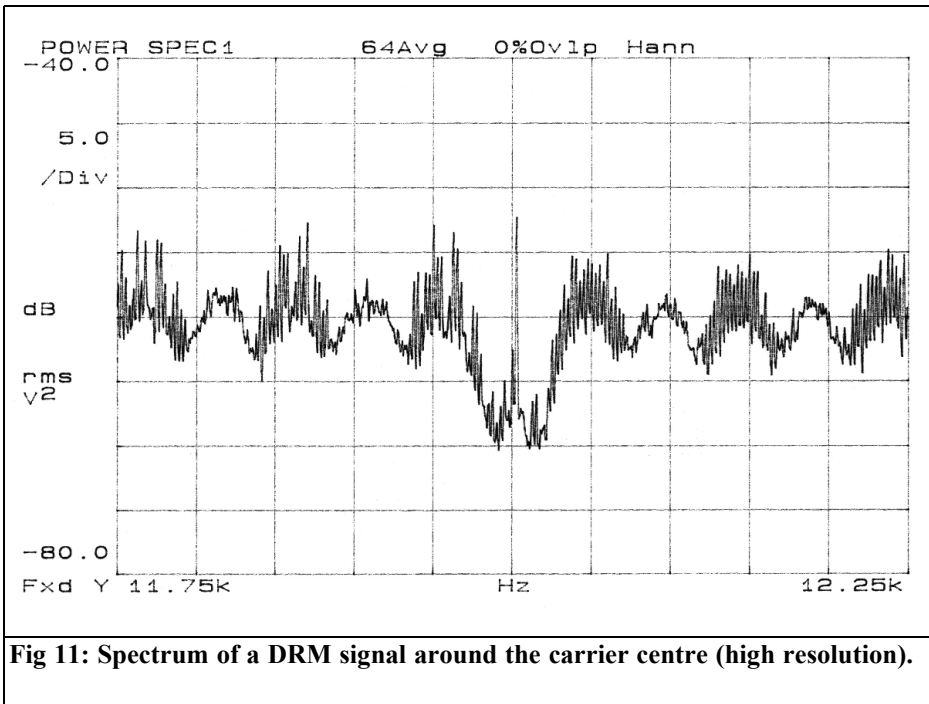
Fig 11: Spectrum of a DRM signal around the carrier centre (high resolution).

3.1. DRM has the following characteristics

- The 9 or 10kHz channels used on the long, medium, and shortwave bands are sufficient
- Further use of existing, modern transmitting plants
- Good reception with low signal/signal-to-noise ratio
- Stability against multi-path propagation in the ionosphere
- Convenient operation as with modern VHF FM receivers with Radio Data System stem (RDS)

In addition the following benefits are:

- A new, efficient audio data compression technique called Adaptive Audio Coding with High Quality Spectral Band Replication (AAC with HQ SBR) supplies VHF FM quality with a data rate around 25kBit/sec.

- The transmission uses digital frequency multiplexing (Orthogonal Frequency Division Multiplex) and splits up the 9kHz channel into 40 to 110Hz wide sub channels that are modulated with a low data rate. Depending upon the system the sub channels are modulated with four-phase quadrature amplitude modulation (2 bits/symbol) up to 64-phase (6 bits/symbol). The long symbol duration makes the system insensitively to multi-path propagation; the multi-carrier procedure has sufficient redundancy that the loss of a carrier by Fading or disturbers can be corrected.
- Interleaving of the data over several 100 milliseconds improves the error correction in the case of bundle errors.

The disadvantage of the system is that despite special synchronisation channels, synchronisation takes a very long time.

Table 1: DRM Modes of error protection.

Mode	Duration Tu spacing 1/Tu Tg	Carrier guard interval Ts=Tu+Tg	Duration of symbol frame Ns	Duration of symbols per	Tg/Tu	Number
A	29mS	41 2/3Hz	2.66mS	26.66mS	1/9	15
B	21.33mS	46 7/8Hz	5.33mS	26.66mS	1/4	15
C	14.66mS	68 2/11	5.33mS	20mS	4/11	20
D	9.3mS	107 1/7Hz	7.33mS	16.66mS	11/14	24

The following points affect this:

- Search of the pilot channels, carrier synchronisation and determination of the mode
- Waiting for the Interleave period
- Error correction and data expansion

The entire procedure takes some seconds, so that it is not possible to carry out a transmitter search in the usual sense. Because modern world receivers have a stored frequency lists and transmission timetables stored in EEPROMs, an automatic search of the data channels in the DRM system could be the solution.

Digital Radio Mondiale cannot replace the normal AM broadcasts. In addition the existence of a billion AM receivers is too large. It will be an interesting alternative for holidaymakers to hear their home stations on a telescopic antenna without systems such as the Internet or a satellite antenna. Only current saving DSP demodulators and AAC audio decoder are missing. So far there are unfortunately only expensive receivers. Phillips have announced a DRM demodulator IC for car radios!

3.2. The DRM modulation format

Channel width:

Standard 9kHz (LW, MW) and 1 kHz (SW), in addition there are half channels with 4.5 or 5kHz spacing and double channels with 18 or 20kHz spacing.

Stages of the error protection (Robustness):

There are 4 stages A to D (Table 1); A is only for channels with Gaussian distributed noise to D for channels with time-variable multi-path propagation with high transit time differences and Doppler shift.

Logical channels:

The Fast Access Channel (FAC) is the synchronisation channel; the Service Description Channel (SDC) is for decoding the multiplexer sub data streams, the Main Service Channel (MSC) contains the data.

Symbol duration:

16 2/3mS, 20mS, 26 2/3mS

Transmission capacity for data:

Depending upon channel width and error protection, 6 to 55kBit/sec (theoretical range 4.8 to 72kBit/sec), 15 to 25kBit/sec is usually used.

Pilot channels:

750Hz, 2250Hz and 3000Hz above the channel cutoff frequency

Signal-to-noise ratio required:

15 to 23dB depending upon channel model (only noise up to multi-path propagation with 6mS transit time difference and 4Hz of Doppler shift), under favourable conditions 10 to 11dB

Data compression audio signal

AAC (Adaptive Audio Coding), optional SBR (Spectral Band Replication) production "synthetic level", alternatively mono or Stereo

4.

Literature:

[1] Analogue and digital modulation procedures, Mäusl/Göbel, Hüthig-Verlag 2002

[2] DVB digital TV, U Freyer, Verlag Technik 1997

[3] The basics of the television engineering, G. Meals , Springer Verlag 2005

[4] ETSI Technical Specification TS 101 980. ver. 1.1.1 (September 2001)

[5] BBC R&D White paper WHP 064, Digitally Radio Mondiale - revitalising the bands below 30 MHz, July 2003

Eberhard L. Smolka, DB7UP

SDR - Software Defined Radio

Thought of as quiet revolution in radio engineering

At the moment there are many new techniques that people are afraid of learning about, particularly those that involve computer assistance. What has appeared quietly and secretly in the distance?

1.
Introduction

Suddenly there is not only traditional receiver engineering with IF and LO, but also more modern techniques that use a software interface. The device that comes to mind is WinRadio. This is such a hermaphrodite that it still uses much receiver circuitry but uses software control and display.

The advantages of Software Defined Radio (SDR) lie in a different place! Theoretically only a good receiving antenna with a super-fast A/D converter is needed that converts the RF directly into a data stream. All further filtering and decoding should then be carried out by software. Thus a universal platform could be used as a receiver without hardware modification for different modulation types and operational modes.

Looking at the different forums it is astonishing to find that all types of projects with different aims are being developed. Naturally these have diverse levels and different objectives. It is wonderful to see that all these different goals can be pursued with different solutions. This applies to all levels of hardware cost.

Depending upon the objective several standards can be used depending on the hardware and software platforms to be used. The hardware is configurable by the software and is therefore very flexible. New standards do not need hardware modification, only a software update.

This is not futuristic but something that everyone can use: For example if a modern mobile phone has a "bug" you can look for a firmware update from the manufacturer. Once this is loaded on the mobile phone the "bug" disappears, so just a software update can keep the device up to date and last longer. This shows that with modern software different things can be achieved e.g. improved performance, lower current consumption on existing hardware.

2.
Different objectives

The possibilities available with new technology under the name of SDR can be roughly divided into the following:

Fig 1: The hardware of the PERSEUS SDR receiver.

- Pure receivers that need an external computer, e.g. PC for the software

- Special receivers for a particular application that are controlled by an external computer

- Special types of receiver that combine hardware and software for a specific application in a piece of equipment

- Transceiver with computer as control unit

- Transceiver combining hardware and software in the equipment

- Pure transmitters that can be used from a computer for all possible modulation types and operational modes

These are completely different applications therefore they need different developments.

For a portable radio base station a hardware platform is desirable that can be configured by software and be changed to the latest operating modes.

An SDR short wave receiver should offer many manually adjustable filters, types of modulation, adjustable attenuator and other adjustments. It is also desirable to show the different signals decoded on a spectrum display.

The current developments naturally differ substantially. An SDR can only be considered as a revolution in the receiver design when the new technology unites hardware and software to surpass the conditions of existing receiver design in terms of in data and comfort! At this point we have achieved our goal.

3.

Examples of current SDR

If pure short wave receivers are compared with the most current SDR developments, some will be rejected but inevitably the promising project "PERSEUS" from Nicolangelo Palermo [3] will be found.

Some of the main characteristics of the receiver that determine its operation are comfort and the demodulation by software.

Instead of inflexible single filters for just
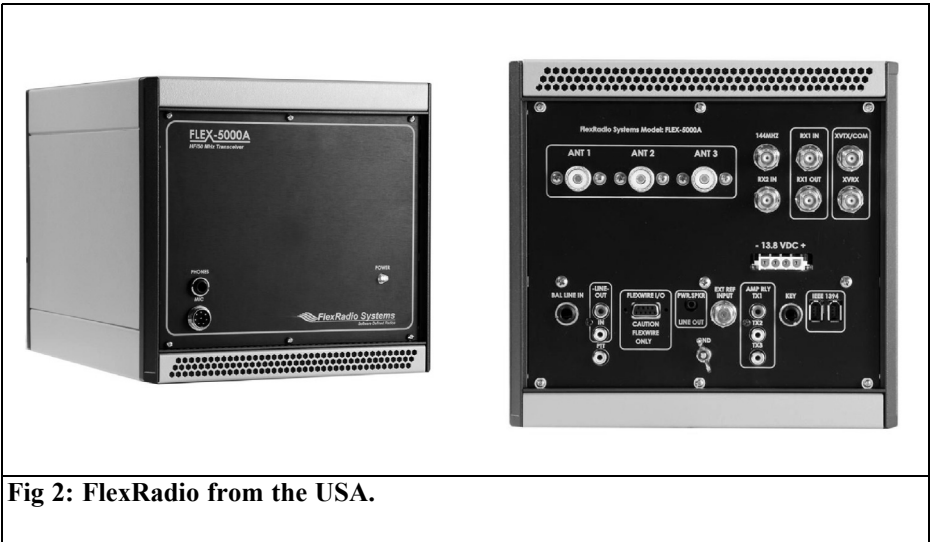
Fig 2: FlexRadio from the USA.

a few ranges, the software operates on the received signal to give a convenient operation that could only be dreamt about in the past. For example a mouse movement can change the filter range, it can be simply shaped simply to the signal either visually or by listening to the result.

Without spending money on auxiliary filters the listener can filter each mode of operation or modulation type using just a mouse click.

PERSEUS can show up to a 400kHz wide frequency range simply as live stream, a mouse click can select the required transmission, it does not get simpler than that! Beautiful things are not seen; a recording of the frequency range is made on a fixed disk and later the individual transmission can be selected from this range as before.

The PERSEUS hardware uses an extremely straightforward concept that can be considered as a universal platform; with appropriate the software interface it offers…

- It is a digital direct conversion receiver without intermediate frequencies and mixer products. It

uses a 14-bit analogue to digital converter that produces 80 million samples per second with a very good SNR of 76dB (40MHz range).

- 10 bandpass filters, a 10 to 30dB three-step attenuator and preamplifier with a 3rd intercept point in the order of +30dbm that helps to avoid overload.

This is a completely different project for the radio amateur developed in Switzerland [4]. The developer, Hans Zahnd, HB9CBU, is working on an SDR Transceiver designed for the needs of the radio amateur. This digital project, TRX ADT-200, operates without an external computer because all of the necessary system software is implemented on an internal processor. The equipment will have four independent receivers and eight internal VFOs for split operation.

Another project is "FlexRadio" from the USA [10] that has been enthusiastically developed for years. It is past the first generation equipment and financial interests have already advanced the development.

4.

View

Contributions for this very interesting topic are encouraged. Perhaps publication of information exchange and expert contributions can develop this new concept. Contact: smolka@ukw-berichte.de (Editor of UKW Berichte)

5.

More information on the topic

[1] A link to a collection of SDR projects at various stages stage: http://f4dan.free.fr/sdr_eng.html

[2] A clear site with many listing: http://www.dxzone.com/catalog/Technical_Reference/Software_Defined_Radio/

[3] The project PERSEUS: http://www.ssb-amateur.de/

[4] Swiss SDR project: www.adat.ch

[5] An SDR project in ELEKTOR May 2007, http://www.elektor.com/magazines/2007/may/software-defined-radio.91527.lynkx

[6] SDR electronics experiment server http://www.elexs.de/drm11.htm

[7] The SDR forum, an American site with commercial background http://www.sdrforum.org/index.asp

[8] Another amateur site: http://hpsdr.org/

[9] GNU radio - The GNU software radio http://www.gnu.org/software/gnuradio/index.html

[10] The FlexRadio: http://www.flex-radio.com/Default.aspx

[11] On the Keithley site there is an on-line seminar http://www.keithley.de/events/semconfs/webseminars/softwaredefinedradio

Andy Barter, G8ATD

G H Engineering PA1.3-100 23cm power amplifier

1.0
Introduction

For the last 10 years I have been using a 23cm power amplifier for contesting using two Mitsubishi M57762 power modules. The amplifier is built into a diecast box with a preamplifier and mounted at the top of the tower to reduce the feeder loss. The power is fed to the amplifier from a 12V gel battery mounted near the amplifier, the battery is float charged from the shack 60 feet below. This arrangement has worked very well but I decided that it was time to try and increase the power output and chose the new PA1.3-100 amplifier from G H Engineering [1]. This is available as a mini kit or a ready built unit; I decided to go for the mini kit and placed an order as soon as the kits became available early in 2008. The following article describes my construction and testing efforts. I hope this will inspire other readers to send me articles on their construction projects that can be published in the magazine. I know that I am not the best constructor but I think that we can all learn something from our fellow radio amateurs, even if it is "I would not have done it like that".

2.0
Circuit description (taken from the GH Engineering documentation)

The PA1.3-100 is a linear amplifier for the 1.3GHz band. It is capable of producing at least 100W in the frequency range 1240 – 1300MHz with a drive level of 3W. The amplifier operates in linear mode, which makes it suitable for SSB operation as well as FM. For best linearity, it is recommended that the input power does not exceed 2W PEP, which will give an output power of approximately 80W at 1296MHz. The amplifier uses four Mitsubishi RA18H1213G PA modules that require no tuning being internally matched to 50Ω at the input and output. An external 13.8V DC power supply is required that is able to supply at least 45A. The amplifier is rated for continuous operation with an input power of 3W and a supply voltage of 13.8V

The PA1.3-100 is intended for use with a transverter of 3W output or similar. It can be used with a 10W transceiver with the use of an external 6dB attenuator. The PA1.3-100 incorporates a 7.5dB input attenuator on the PCB; this can be changed or removed if required, thus allowing the amplifier to be used with an

Fig 1: Picture of the circuit diagram for the PA1.3-100 23cm power amplifier.

Fig 2: Picture of the kit for the PA1.3-100 23cm power amplifier.

input signal down to approximately 750mW.

Fig 1 shows a photograph of the circuit diagram that is printed on an A3 sheet so it is not really suitable for reproduction on an A5 page in this magazine but the main elements can be seen to help understand the following description of the RF distribution.

The RF input signal is split with a Wilkinson splitter and each of the two signals is then split again with two more splitters. This gives four signals of equal amplitude and phase that are attenuated by approximately 7.5dB by pi-networks.

Each RA18H1213G module provides a small signal gain of approximately 23 –

25dB depending on frequency. The input and output microstrip lines have been designed to ensure that the overall amplifier gain is as flat as possible over the 1240 – 1300MHz band.

The output signal is fed to a 4-way Gysel combiner, which is a derivative of the N-way Wilkinson combiner. It consists of 4 quarter wave transmission lines, each 100Ω impedance. Therefore the output signal is transformed to 200Ω, which gives an output of 50Ω when all four are connected together in parallel, The isolating network is somewhat more complex than for the input splitters. ¾ wavelength transmission lines are connected to each of the junctions of the 50Ω and 100Ω lines. The ends of these lines are termi-
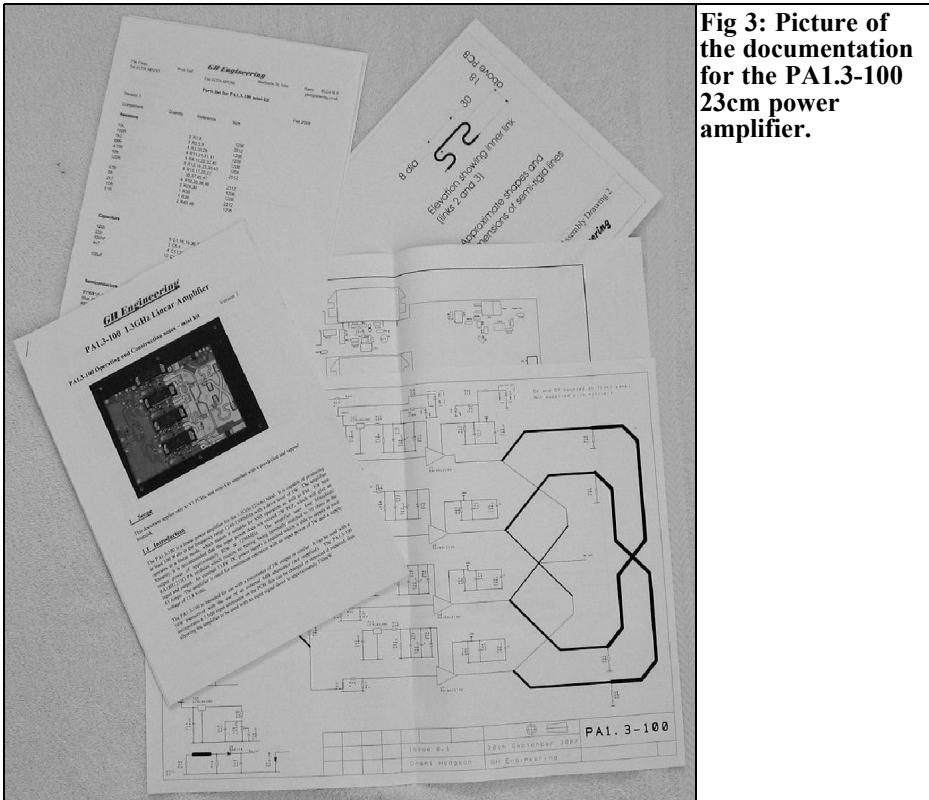
Fig 3: Picture of the documentation for the PA1.3-100 23cm power amplifier.

nated with 50Ω high power terminating resistors. This is also connected to the end of another quarter wavelength line, of 25Ω impedance. These four 25Ω lines are connected together. At this point there is a virtual ground, in that no current flows across the junction, but the impedance is actually very high, and approaches an open circuit. Therefore the impedance at the termination resistor is very low (approaching a short circuit) and no power flows into the resistors. Therefore, the impedance looking into the end of the ¾ wavelength lines is very high. Consequently, the ¾ wavelength line places no load on the output, and no current flows into the isolating network.

The PA1.3-100 is fitted with a PCB temperature sensor giving an output voltage that is proportional to temperature. The voltage gradient is 10mV/°C and the voltage is directly proportional to absolute temperature in Kelvin. Therefore at 20°C the output voltage would be 2.93V and at 50°C would be 3.23V.

There is an output power detector using a sampling line and a BAS-70 diode. The output voltage developed is dependant on temperature, to compensate for this dependency a second diode is fitted. A simple power meter can be made using a operational amplifier that compares the output voltage of the two diodes.

Both the temperature sensor and power detector are provides as unsupported features for the constructor to use as they see fit. I have not been able to make either of these features work properly. They both suffer from RF pick-up. The temperature sensor works well when the
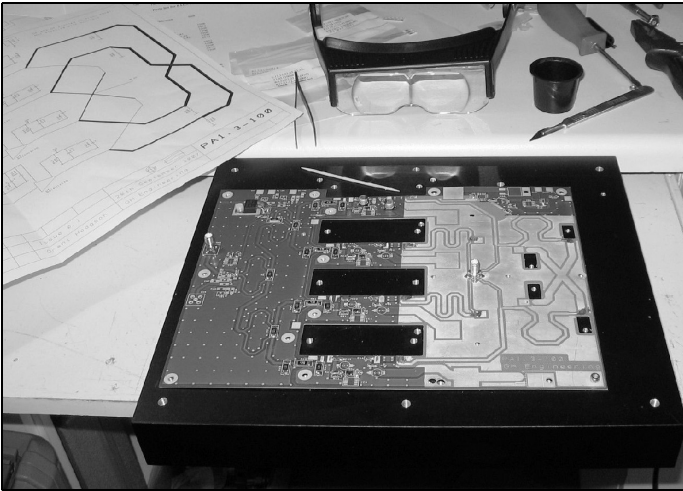
Fig 4: Picture of the PCB mounted on the heatsink as a workbench to hold the PCB still while fitting the SMD components.

amplifier is not producing power and it is quite useful to know the temperature. The power sensor has been designed with the diodes that are reversed compared with the circuit diagram and the power reading can only be taken as an indication of output and changes when the lid of the case is fitted.

3.0

The kit

The kit comprises of all the electronic components, a pre-drilled heatsink and a set of documentation. Fig 2 shows the kit of parts and Fig 3 shows the documentation and parts list. The first task was to check that everything was present. Thoughtfully the SMD were split into several self-seal bags with the values on a list stuck to the bag. Because some components are difficult, or impossible, to identify the bags are split so that the components can be identified by the quantity of each in the bag. I made a note to keep the components in their bags until I used them so they did not get mixed up.

The next thing to do was to read the

assembly instruction to make sure that I knew of any special requirements during assembly. There were a few modifications to do to the PCB and a decision to be made about the sense of the PTT switching. Fortunately I wanted PTT switched to ground for transmit since one of the PCB modifications made it impossible to fit the additional components for PTT going high for transmit. The remaining instructions looked straightforward SMD assembly followed by some care required when mounting the four power modules.

4.0

Construction

The heatsink is a hefty piece of aluminium and made a suitable place to mount the PCB and hold it still for assembly of the SMD components (Fig 4). Because there were a few errors on the circuit diagram and the component layout care had to be taken to double-check each part as it was assembled but assembly of all the SMD parts was straightforward. The only point to note is that any component connected to the
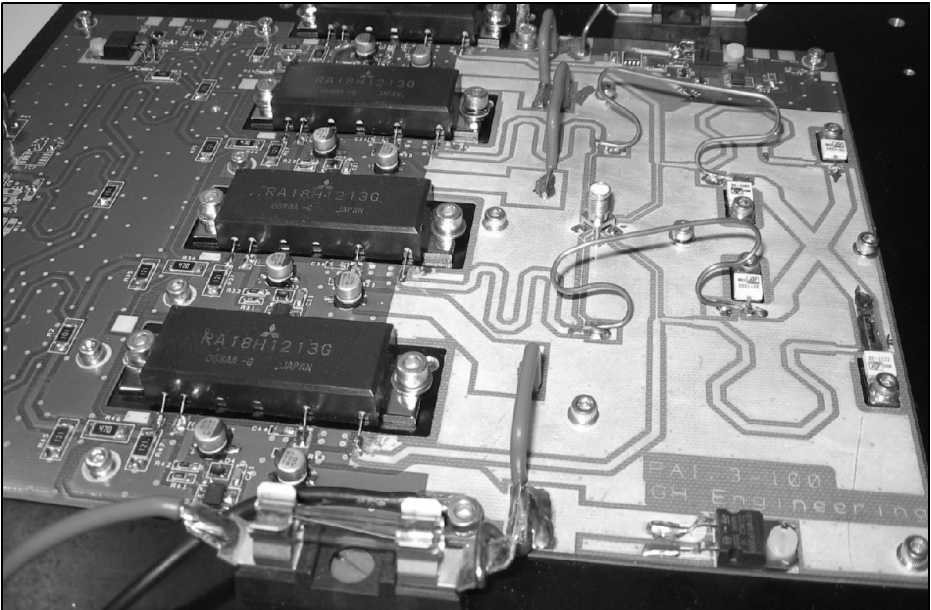
Fig 5: Picture of the 3/4 wavelength lines fitted to the output circuit.

ground surface needed an extra bit of heat to make a good solder joint, so I used two different bits on my old Weller soldering iron. If you have a more modern soldering station this may not even be noticeable.

Once all the SMD components are fitted the instructions require some voltage checks before the power modules are fitted. In my case the voltage measurement of the top power module bias supply was not correct. This was quickly traced to the monitor LED that placed an extra load on the circuit. A quick wire link to a different supply point and all was well.

The next step was to fit the two ¾ wavelength lines that are made from semi rigid cable. Some care was required to make these and shape them as shown on the diagram in the instructions. My attempt at this is shown in Fig 5

The final step was to bolt the PCB to the heatsink and fit the power modules.

Static precautions must be taken when fitting the power modules because they are sensitive to static electricity. The instructions mention that the mounting holes for the power modules must be as clean as possible to provide a good DC and RF path to the power modules, some cotton buds are provided to clean the tapped holes in the heatsink. Thermal transfer paste was spread on the centre (slightly recessed) section on the base of each power module before it was bolted down to the heatsink

Because I wanted to mount the amplifier on the top of the mast I wanted the finished unit to be weather proof and did not want to mount the two fans on the heatsink. After a quick conversation with Grant Hodgeson at G H Engineering we decided that the fans are needed if the power amplifier is going to be used continuously for FM or ATV, because my use was intermittent SSB and the amplifier will be in the open air the fans could be dispensed with. This meant
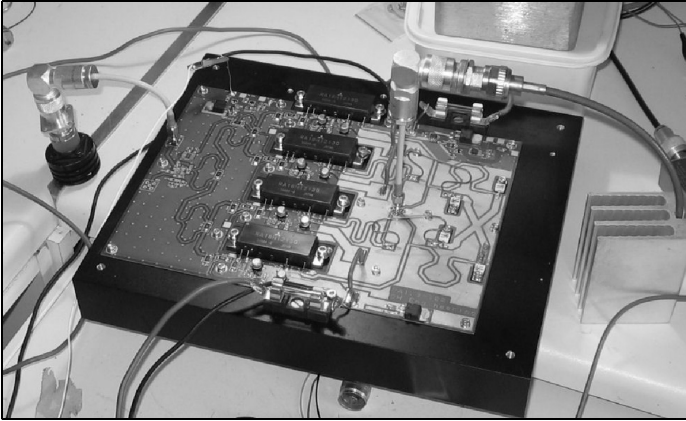
Fig 6: The completed PCB ready for initial testing.

blocking up the tapped holes in the heatsink used to mount the fans, this was done using Allen screws coated with silicon sealant.

The completed power amplifier is shown in Fig 6, ready for initial testing.

5.0

Testing and fault finding

To make initial test the amplifier was fitted with a dummy load on the input and output. The instructions state that the current drawn by the power amplifier with no RF input should be approximately 15A so I intended to use my 25A

Fig 7: The output of the amplifier when it was self-oscillating.

bench power supply for the initial test. When I switched on the power supply went into current overload, so I knew there was a problem.

The final method of powering the amplifier was to be a 38AH sealed lead acid battery so that was connected up and the amplifier was actually drawing 26A with no RF input. A quick check showed that the amplifier was producing about 10W output on random frequencies (Fig 7); it was self-oscillating. An email to G H Engineering indicated that the mounting holes for the power amplifiers were probably not clean enough or some thermal paste had oozed under the mounting flanges.

The modules were removed, holes cleaned and a small spot of thermal paste removed from one of the modules. The method that I used to clean the holes was to shave down a cotton bud and spray it with degreasing cleaner then "screw" it into the tapped hole. When the amplifier was switched on again it still drew 26A but the output was now on a single frequency. By grounding the control, pin (Pin 2) on each power module in turn the oscillation was isolated to power modules 3 and 4. Again the problem was thought to be poor grounding of the power module so some brass strips were fitted to improve the grounding of modules 3 and 4 (Fig 8) but this did not solve the problem.

Fig 8: Picture of the additional grounding on modules 3 and 4.

After carrying out more checks it was noticed that pressing the PCB around the general area of power module 3 and 4 stopped the oscillation; this was the clue. The mounting screws for the PCB to the heatsink were loosened on one side and re-tightened with the PCB pressed firmly against the heatsink. The amplifier then drew 15A and no oscillation.

Next the amplifier was fed with 23cm RF and the output measured, with 12.5V at the battery terminals 87W output was measured. To get full output the full 13.8V supply would be required. To do this the power supply wiring had to be tidied up, it is surprising how much volt drop there can be across a thick piece of cable when it is carrying the 40 or so amps drawn at full power.

The amplifier was then fitted into its box to tidy up the wiring and fit the final input and output connections to the changeover relays. I spent some time researching the possibilities for an enclosure; my first thought was a diecast aluminium enclosure with a fully sealed lid, having seen the price and weight of suitably sized enclosures, there had to be a better option. While searching the Farnell web site I found that there is a range of steal terminal enclosures [2] that are fully sealed at a reasonable price and weighing less than the equivalent size aluminium enclosure (the aluminium enclosures are built to support a tank). The only problem with this enclosure is cutting out a 200mm x 250mm hole to fit the power amplifier. The result is shown in Fig 9.

Final testing with everything tidied up gave nearly 100W output

The acid test was use under contest conditions. I used it for the May 2008 UHF/SHF contest and it performed faultlessly. Unfortunately conditions were poor so the DX was not great but all reports were good

Fig 9: The amplifier mounted in its metal enclosure with a sequencer and a preamplifier.

6.0

Conclusion

The PA1.3-100 RF circuitry is well designed but is let down by some silly mistakes in the documentation but mine was one of the first kits to be shipped. I hope that these will be corrected and then the kit will be easy to build by anyone with a reasonable level of experience. The amplifier performs well and does exactly what it says on the tin.

The main thing to take note of when using the amplifier is that a 45A 13.8V supply is difficult to provide at the top of a mast but I think the advantages of mounting the amplifier near the antenna for contest working outweigh the problems involved. If I were using the amplifier for a permanent installation this would need careful thought.

7.0

References

[1] G H Engineering, The Forge, West End, Sherborne St. John, Hants, RG24 9LE, Tel: 01256 889295,
Fax 01256 889294, email:
sales@ghengineering.co.uk, web:
http://www.ghengineering.co.uk/products/1.3GHz.htm

[2] Terminal boxes from Farnell:
http://www.farnell.com/datasheets/77332.pdf, I used the KL1508 400 x 300 x 120mm box.

Zeljko Bozic, S52ZB

Additional unit for the S53MV frequency counter

(More accuracy and RS232 interface)

1.

Introduction

Every frequency counter is only as accurate as the accuracy of its frequency reference. Therefore I replaced the crystal in S53MV frequency counter [2] with a TCVCXO and on the same PCB I have combined some additional functions.

On the PCB measuring only 50 x 37mm are a 10MHz TCVCXO (±0.5ppm), external reference input, internal/external reference switching, borrow reference, frequency multiplier (x2) and an RS232 interface. It has an extraordinarily low power consumption (16mA), ideal for portable use.

There is no need to make a new housing because the additional PCB is designed so that it will fit, without any trouble, into the existing housing.

2.

Circuit diagram

The circuit diagram of the additional unit is shown in Fig 1.

A very small value of ppm is required for the frequency reference; therefore I have used a good quality crystal oscillator (±0.5ppm, 0-50°C). The crystal oscillator used is a miniature C-MAC TCVCXO CFPT-9001 [3].

Internal/external reference switching is carried out using a miniature SPDT toggle switch. So that the TCVCXO wouldn't be loaded the borrow reference output is connected through more buffer stages (inverters) and 100Ω resistor for short circuit protection.

A times two frequency multiplier is realised with an EXOR gate and RC network. The 10MHz signal is multiplied by its delayed replica in the EXOR gate (pin 4, 5 and 6). Frequency multiplication needs a 90 degrees phase shift (25ns at 10MHz) to operate. One HC gate delay some 10ns, the RC network contributes the rest.

Today we almost can't think of a measuring instrument without connection to a PC, therefore I have added an RS232 interface with an SP233A [4]. The results of measurements can be saved in a file and later used to make a diagram. This possibility is interesting for long-term measurements and later comparisons of measured results.
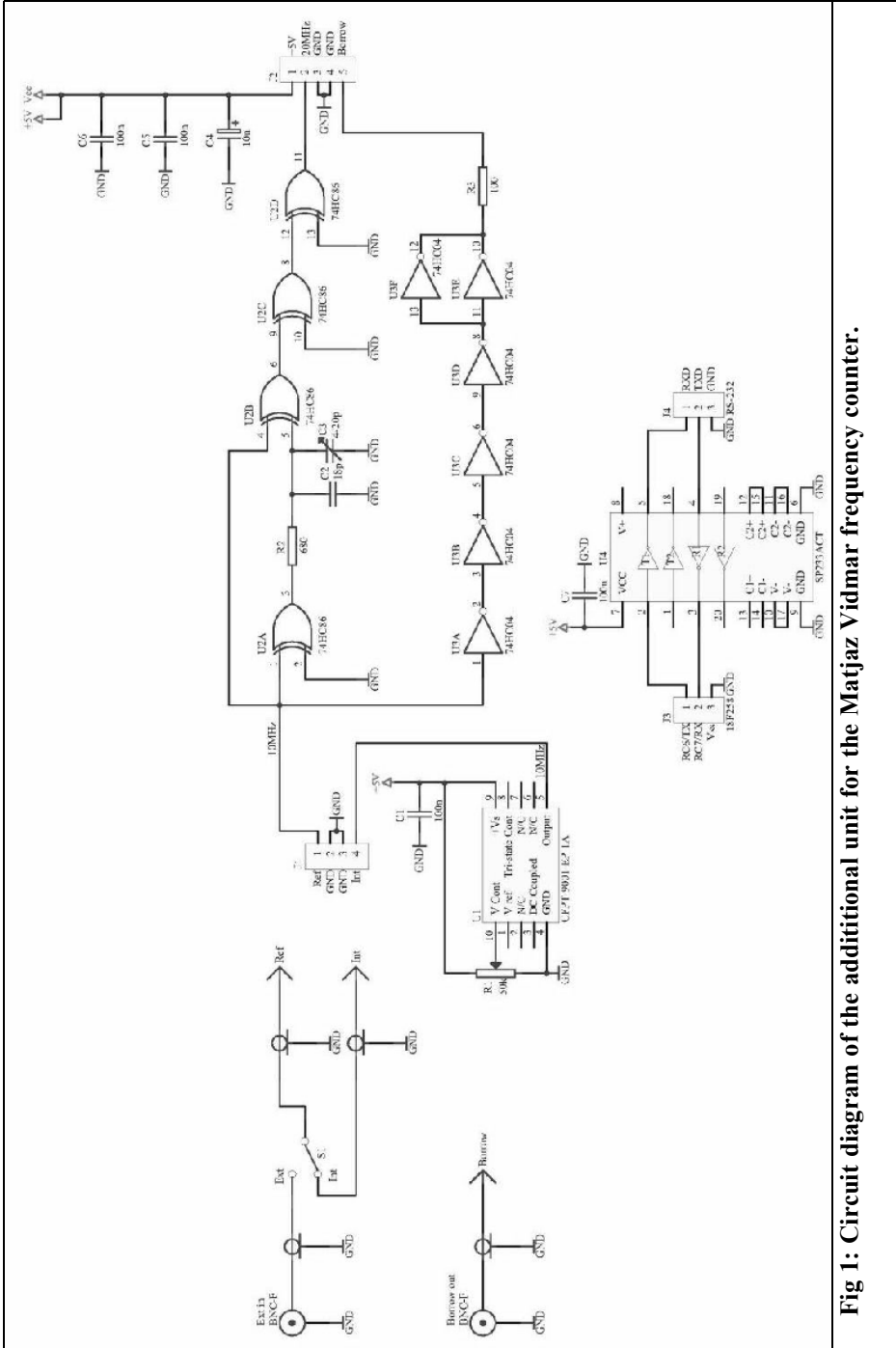
Fig 1: Circuit diagram of the addititional unit for the Matjaz Vidmar frequency counter.
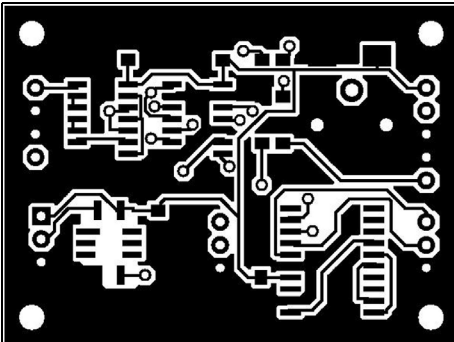
Fig 2: Top side PCB layout for the additional unit.
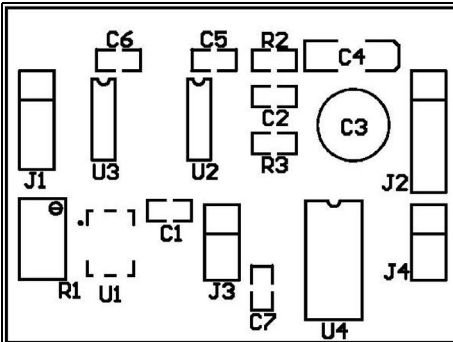
Fig 4: Component layout for the additional unit.

3.

Construction

The additional unit is constructed on a double-sided PCB made from a 50 x 37mm piece of 1.6mm thick FR4 laminate. It has plated through holes, solder resist, lead free tinning and legend marking. The PCB layouts are shown in Figs 2 and 3, the component layout is shown in Fig 4 and the parts list in Table 1.

The adjustment of the additional unit should start with the adjustment of TCVCXO frequency and delay of the frequency multiplier.

For adjustment, connect pin 1 and pin 4
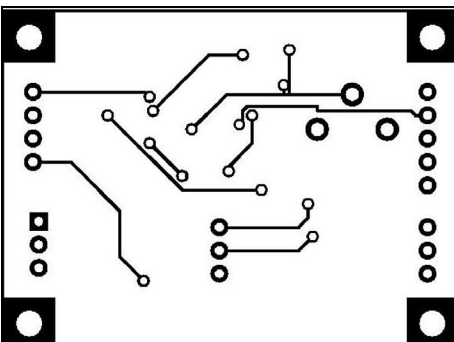
Fig 3: Bottom side PCB layout for the additional unit.

on connector J1. With the multi-turn trimmer R1 adjust the TCVCXO frequency for 0.1Hz accurate measured on connector J2 pin 5 (Borrow). The frequency is adjusted with help of a frequency counter, a more accurate adjustment can be made with the help of oscilloscope by the Lissajous method.

The capacitive trimmer C3 is adjusted to obtain an average (DC) voltage of 2.5V on pin 6 of the 74HC86. A DC voltmeter is connected to pin 6 of the 74HC86 through a RF choke. A 10kΩ 1/4W resistor may also be used as a RF choke.

The 40MHz software version doesn't need multiplier; therefore we can use

Table 1: Parts list.

Item	Value	Size
R1	50kΩ	64W, multi-turn
R2	680Ω	0805
R3	100Ω	0805
C1, 5, 6, 7	100nF	0805
C2	18pF	0805, NP0
C3	4 - 20pF	TRIM22P
C4	10µF	C, Tantalum 35V
U1	CFPT-9001	SMD 7 x 5 x 2mm
U2	74HC86	SO-14
U3	74HC04	SO-14
U4	SP233ACT	SO-20 wide
J1		4 pin
J2		5 pin
J3, 4		3 pin
S1		SPDT switch
BNC-F		BNC female
PCB		50 x 37mm, FR4 1.6mm
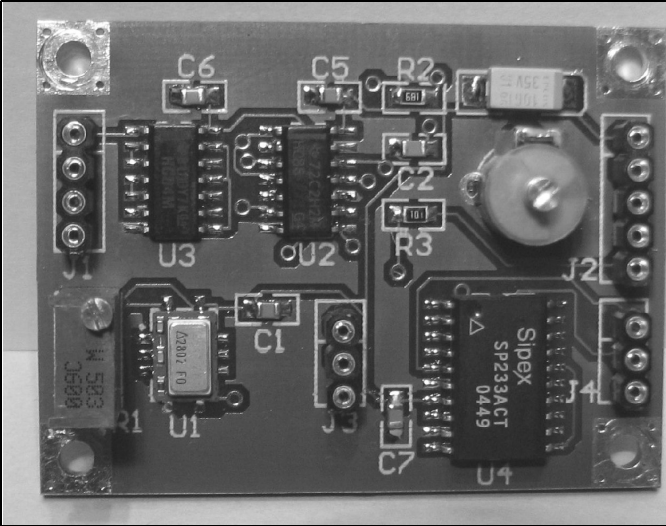
Fig 5: The completed PCB for the additional unit.

gates of 74HC86 as buffer stages.

The 20MHz signal has to be connected to pin 9 (OSCin) while pin 10 (OSCout) is left open. For this use the existing holes of the crystal oscillator or trimmer, for ground drill an additional hole or two. Before this remove superfluous component parts (20MHz crystal, 22pF trimmer, 2µ2 choke, 33pF capacitor, and 330Ω resistor).

The input of the RS232 interface has to be connected to pin 17 (RC6) and pin 19 (Vss). For this, drill three additional holes beside the LCD connector.

All components used, except trimmer C3, are SMD. Capacitor C2 is NP0 ceramic;

capacitive trimmer C3 is a 7.5mm diameter green plastic foil type. The marking code for the 10MHz CFPT-9001-EP-1A is 2802. All RF signal connections are made with thin teflon coax (RG-188, RG-316). A low profile good quality 2.54mm SIL sockets are used as connectors.

The additional unit is fixed on the rear wall of the housing. I have reduced the fixing holes in proportion to the PCB size. The fixing holes of 2.7mm diameter are designed for M2.5 screws. The prototype of the additional unit is shown in Figs 5, 6, 7 and 8.

With the additional unit I have improved the accuracy of frequency counter by
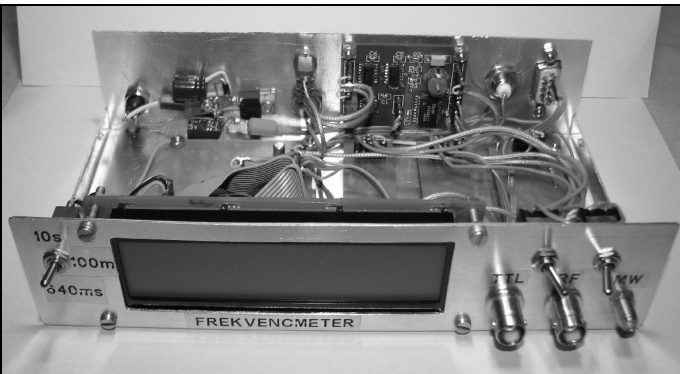
Fig 6: The completed prototype fitted in a frequency counter.
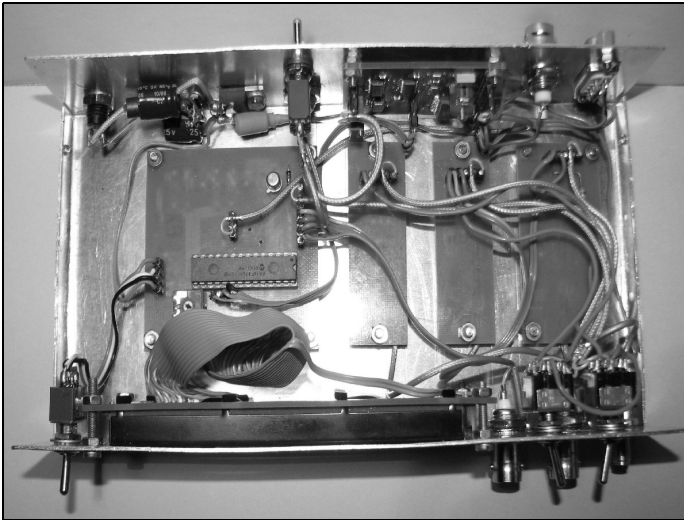
Fig 7: Completed counter.

approximately 100 times and I gained some very useful functions. If better accuracy is needed, it is recommended to use the highly accurate frequency source [1].

4.

Software

Sandi (S54S) has rewritten the software used with the PIC16F876A for the more recent (and faster) PIC18F258, which is pin compatible. The software works with a 10MHz clock and internal PLL x 4 for fast execution of program code. Two software versions are available, for 20MHz and 40MHz clock. The last version doesn't need frequency multiplier.

The LCD is driven in 4 bit mode. This releases four I/O pins, two of them are used for additional functions and two are still available.

UART TXD output, which is on RC6 sends data at 9600bps, 8N1. The data packet is terminated with CR and LF, the packet content is coded in ASCII so that you can immediately see what individual parts (content) mean.
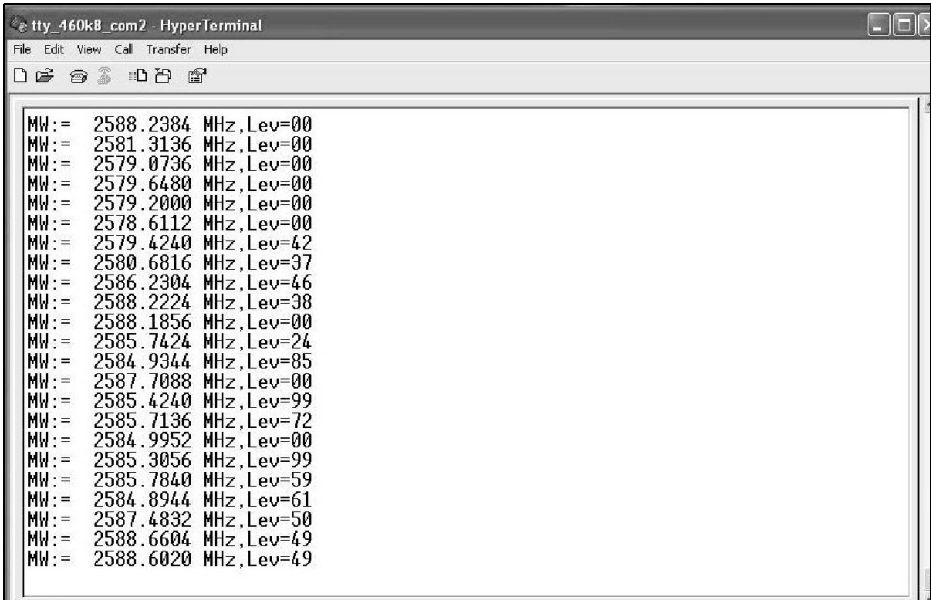
Using HyperTerminal (Fig 9) you can see data is sent from the frequency counter to a PC via RS232. The level range is from 00 to 99 (99 = full scale on the bar indicator). An additional possibility is to connect a second microwave unit (MW2) with divider modulus of 1000.

Free software versions for the PIC18F258 are available from the author: Aleksander Stare, Sandi (S54S), email: s56al@email.si.

I wish to thank Sandi (S54S) for the PIC software and Stojan (S51WI) for help in all phases of project.

Fig 8: Connectors of the additional unit.

Fig 9: Hyper Terminal screen showing the data output from the RS232 port on the additional unit.

5.

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http://www.exar.com/Files/Documents/sipex/datasheets/sp232_312a.pdf

John Fielding ZS5JF

John's Mechanical Gem No. 2 Marking out

1.0

Introduction

When an item needs to be made the accurate positioning of holes is a common problem. Trying to mark out a series of holes using a steel ruler and a scriber is difficult and any errors spoil the finished product.

Typically when working from a drawing it is best to work from one common point on the piece of metal being used. This is commonly known as a "datum point" and it may be one corner or a particular hole.

Let us take an example to demonstrate an easier method. The item in Fig 1 is the cover plate for some item and it will be held in place by several screws tapped into the other part. The thing to notice is that the centre line has been drawn along the length of the item. It may well be that a piece of metal of the exact dimensions is not to hand, but a piece close to the dimensions is a standard stock item. So the centre line serves a very important factor because we use this as the datum point for one axis of the part.

It is of great assistance, if when the drawing is made, that the center-line is clearly identified and this is a good habit to get into when drawing parts for subsequent manufacture. It also reduces "clutter" of unnecessary additional dimensions because by inference the centre line is exactly midway between two opposite
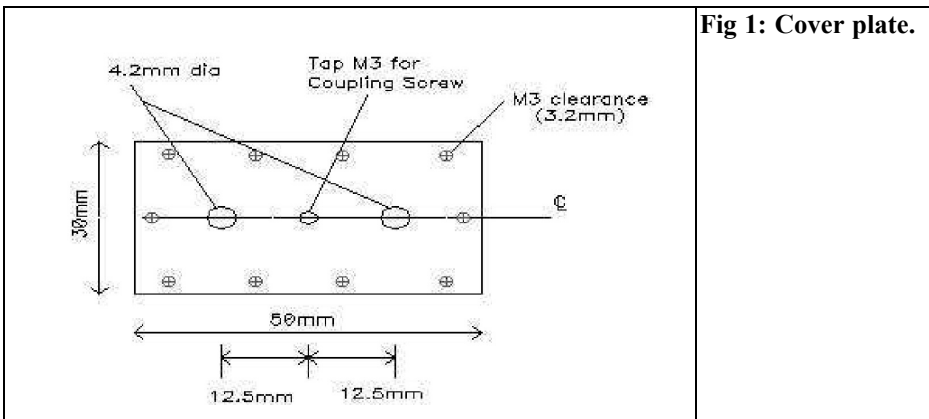
Fig 1: Cover plate.

Fig 2: Set square, scriber and dividers.

edges. It is not necessary to tell the constructor "the center line is 15mm from the top or bottom edge"; the statement implies this.

Suppose the holes indicated as M3 clearance are required to be 7.5mm from the edge of the item. It is very difficult using a steel ruler and scriber to accurately mark this on the metal. But there is a much simpler and more accurate method that uses a vernier caliper. Other holes could be located and scribed by a pair of dividers, similar to drawing compasses but with two sharpened points. Fig 2 shows a typical scriber, set square and a pair of marking out dividers.

Fig 3:Typical vernier caliper with dual scales.

Fig 4: Depth measuring end of a vernier caliper.

2.0

Vernier Calipers

Vernier calipers are made in several standard sizes, the smallest being about 100mm (4 inch) in capacity. Although relatively expensive, once purchased you will wonder how you managed before you owned one. Today many tools are made in Mainland China, which are

Fig 5: Scribing a line with the vernier calipers.

relatively inexpensive and good quality. Choose a size that will suit the majority of your work, there is no need to have more than, say, two in your toolbox.

Some vernier calipers are only graduated in millimeters, but some are made with dual scales, both metric and imperial and one of these would be a good choice (Fig 3). Although imperial measurements are regarded as old fashioned you will be amazed how many components used in RF engineering are made in imperial dimensions, even today, because there is no metric equivalent.

Virtually all vernier calipers made also have a very useful extra feature; they can measure the depth of a hole. This is an extending tail that is calibrated off the main scale (Fig 4).

To mark out the fixing holes to the correct dimension from each edge we firstly set the vernier to the required dimension and then lock the caliper by the screw on the top of the slide. Now we hold the piece of metal in one hand and the vernier calipers in the other and run the tips along the edge. The tips are ground to a point and this leaves a fine line scribed into the metal (Fig 5).

Marking out the central holes about the centre line is also simple with the vernier calipers. On the top of the jaws are two

Fig 6: Using the internal jaw tips to mark the bores centres.

extra tips, which are intended for measuring internal diameters. These are also ground to a fine point and can serve as dividers. Firstly we need to find the exact center of the metal, which we can easily do by measuring the major axis in the X and Y direction. Having ascertained the dimension we divide the measurement by two and reset the vernier to this dimension. Now working from one edge we use the outside jaws to scribe a line, which is the centre line. The intersecting line in the middle is now scribed using the same method. Then from this point with the vernier reset to the dimension of the bores from the middle, we scribe another line using the internal jaws like a divider (Fig 6).

Gunthard Kraus, DG8GB

Internet Treasure Trove

Orban Microwave

There are several interesting Application Notes for microwave and antenna enthusiasts: e.g. Basics of antenna arrays, Basics of patch antennas, An introduction to GPS patch antennas, An introduction to GPS low noise amplifiers etc.

Address:
http://www.orbanmicrowave.com/appnotes.htm

100GHz Subharmonic mixer

Those who are interested in the current state of high frequency mixer development should look at this publication. It is very informatively, easy to understand but nevertheless very accurately. A good article like this looks good and extends your knowledge.

Address:
http://www.eecs.umich.edu/rebeiz/Completed%20Research%20Papers/W_Band_Subharmonic_Mixer97.pdf

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symposiums/symp11/
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