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Circulators and Ring Hybrids

For protecting VHF high-level stages and for decoupling VHF control transmitters

In practice a transceiver is used to drive a power amplifier. If the power amifier is tuned and a brief self-excitation takes place, which can easily happen in standby mode, the receiver input transistor can be destroyed.

In contests each operator uses his or her own transceiver, but they all use the power amplifier. Matching the transceiver output impedance to the power amplifier input impedance leads to great variations in output, although all transceivers are providing the same driving power.

The solution to these problems usually lies in using circulators and hybrids.

1. Basics

This article is concerned exclusively with circulators and with hybrid quarter-wave circulators. The way they work is briefly explained, and this is followed by practical assembly suggestions. Circulators are among the oldest microwave ferrite components in technical use. Their transmission behaviour is influenced by a large number of magnetic and geometric parameters, which makes them difficult for amateurs to manufacture and also makes access to them difficult. Optimisation with regard to band width and transmission losses is also difficult to arrange.

The functioning of the circulator should be described first. Circulators have a pre-magnetised ferrite body as their essential component, which absorbs the electro-magnetic wave in one direction but leaves it uninfluenced in the other.

The way the circulator works should become clear from Fig 1.

The power from the VHF amplifier is passed on to the antenna in the direction of rotation of the circulator. The power reflected from the antenna, e.g. due to a poor SWR, is also passed on to the dummy load in the direction of rotation and is there converted into heat. The VHF amplifier discovers an ideal SWR in every case.

An open (blank) circulator arm can not absorb any power, i.e. it feeds it on to the next arm in the direction of rotation.

In the same way, the circulator protects a transceiver against a poor input SWR from the subsequent amplifier stage. (Fig 2) The transceiver sees an ideal SWR in any tuning position. Because of the special ferrite body, which all

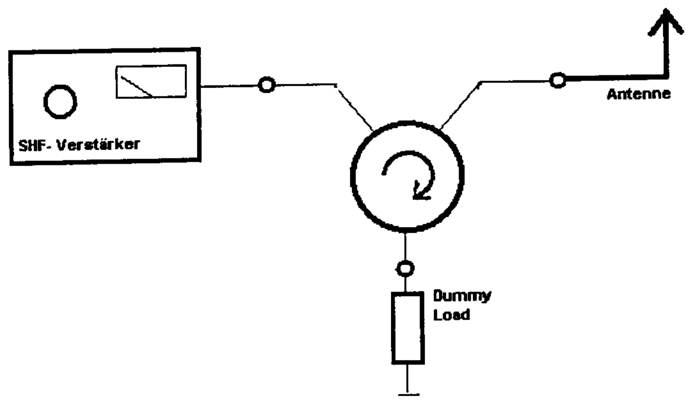

Fig 1 Using The Three Port Circulator to Isolate an Amplifier from an Aerial

circulators have in common, this microwave component is not suitable for production on a DIY basis.

2. Decoupling Between Transceiver and PA Using Hybrid Quarter Wave Circulators.

Quite usable results can be obtained using the hybrid quarter-wave circulator (Fig. 3), if it is correctly dimensioned. It also provides a measuring output for tuning the input circuit. As can be seen in the sketch in Fig 4, this microwave component consists of four lambda/4 circuits with different impedance levels, which are inter-connected to form a ring. However, the power delivered from the input to the usable output is not 100%, as for the circulator, but only

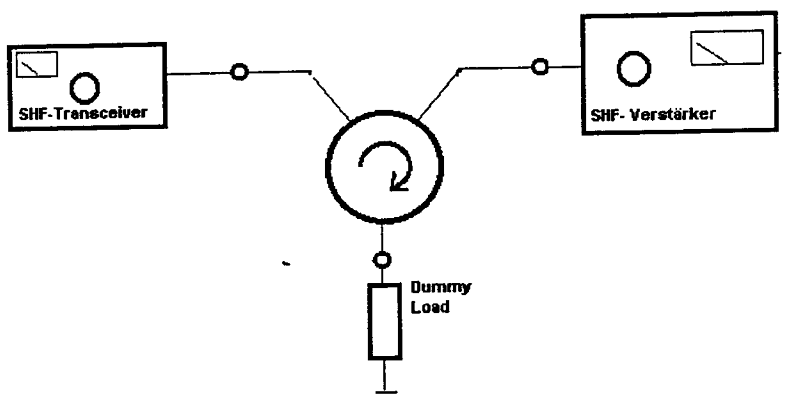

Fig 2 Using the Circulator to Isolate a Tranceiver from a Power Amplifier

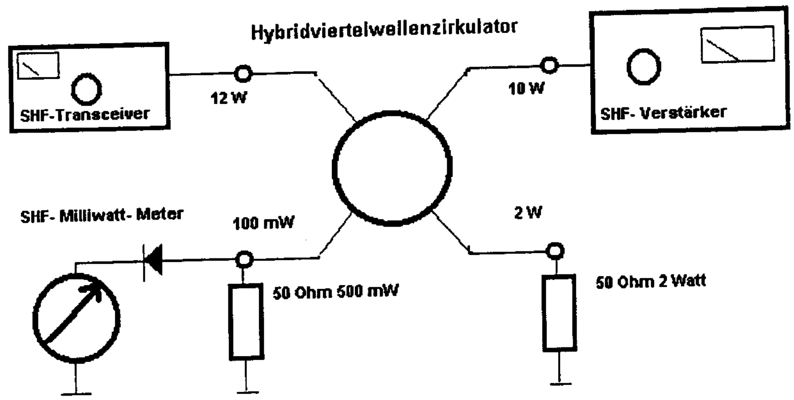

Fig 3 Using the Hybrid Quarter Wave Circulator

a maximum of 86 %. Moreover, the filter attenuation is considerably worse. The four ports of the hybrid in this application are defined according to Fig 5. Power applied at port 4 splits, rotating clockwise, onto ports 3 and 2. At the measuring output, the signals cancel each other out due to phase opposition. Port 1 is completely de-coupled from port 4. Likewise with this layout ports 2 and 3 are completely de-coupled. However, the input and the usable output of the ring coupler are not completely de-coupled. This is connected with the fact that energy reflected from port 3, rotating anti-clockwise, splits in equal proportions onto ports 4 and 1, whereas power fed in at the input, rotating clockwise, splits onto ports 3 and 2. If port 3 is used as input, then the power supplied, rotating anti-clockwise, splits in equal proportions onto ports 4 and 1. In this case, ports 3 and 2 are completely decoupled. Ports 4 and 3, however, are only de-coupled for half their amplitude, because input and usable output can be transposed in both examples. This means that the power transmitted from the input (port 4) to the usable output (port 3) is reflected from the changing load at port 3 and splits onto ports 4 and 1 in defined proportions. A milliwatt meter connected to port 1 indicates the reflected power at port 3 due to a miss-matched load (connected VHF PA input). The high-level stage input circuit need only be

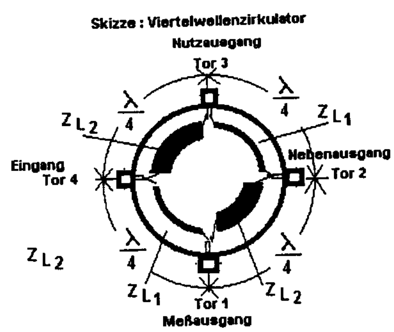

Fig 5 The Four Ports of the Hybrid Quarter Wave Circulator. (Eingang = Input, Nutzausgang = Useable Power Output, Nebenausgang = Dummy Load Output, Messausgang = Measurement Output

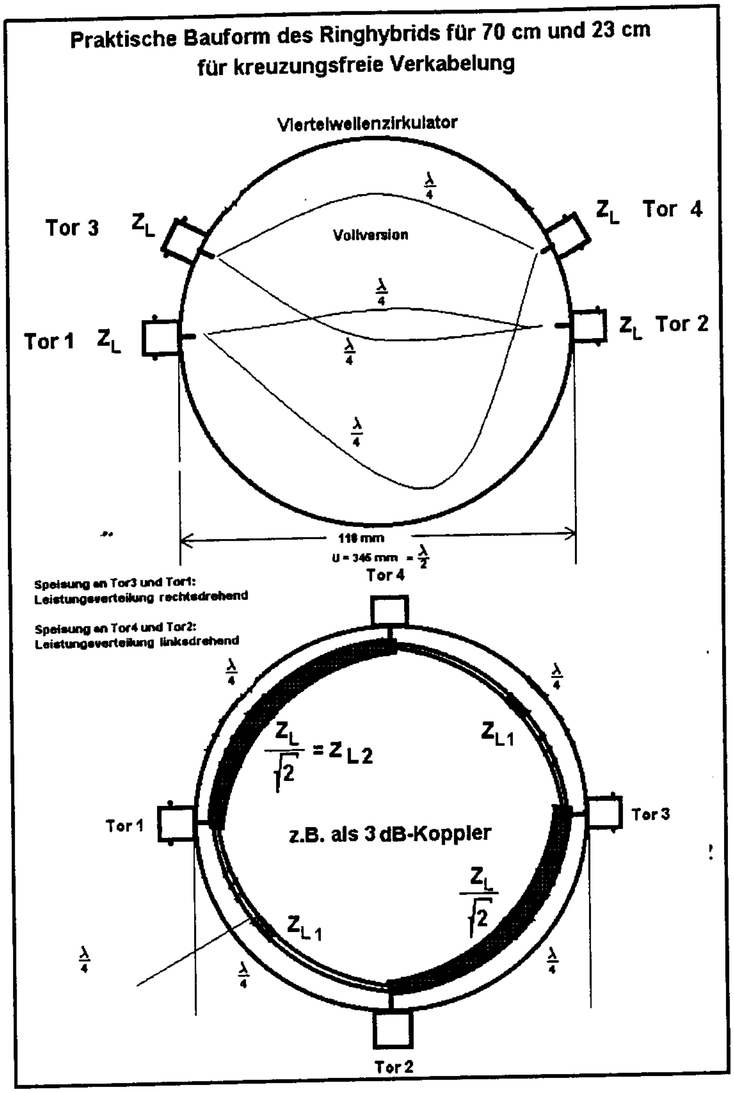

Fig 4 Sketch of Hybrid Quarter Wave Circulator

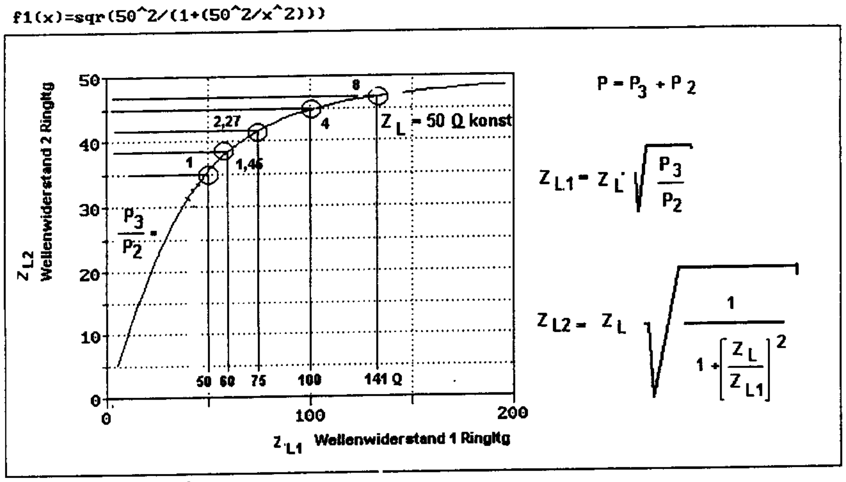

Fig 6 Results of Calculations of Hybrid Quater Wave Circulator

tuned at the minimum amplitude of the milliwatt meter at port 1. The reactive components present in the hybrid are now compensated by the reactive components of the input circuit. i.e.: a conjugate complex tuning has taken place. What can be explained only with difficulty in theory has an amazing effect in practise. The control transceiver always sees an equally good input SWR almost irrespective of the tuning condition of the VHF high-level stage.

Table 1 Division Ratios Possible

	ZL1	ZL2	ZL	a_n
$\frac{P3}{P2} = 1$	50 Ω	35 Ω	50 Ω	3 dB
1,45	60 Ω	38 Ω	50 Ω	2,3 dB
2,27	75 Ω	41 Ω	50 Ω	1,6 dB
4	100 Ω	44 Ω	50 Ω	0,9 dB
8	141 Ω	47 Ω	50 Ω	0,5 dB

a_n = Durchgangsdämpfung zum Nutzausgang

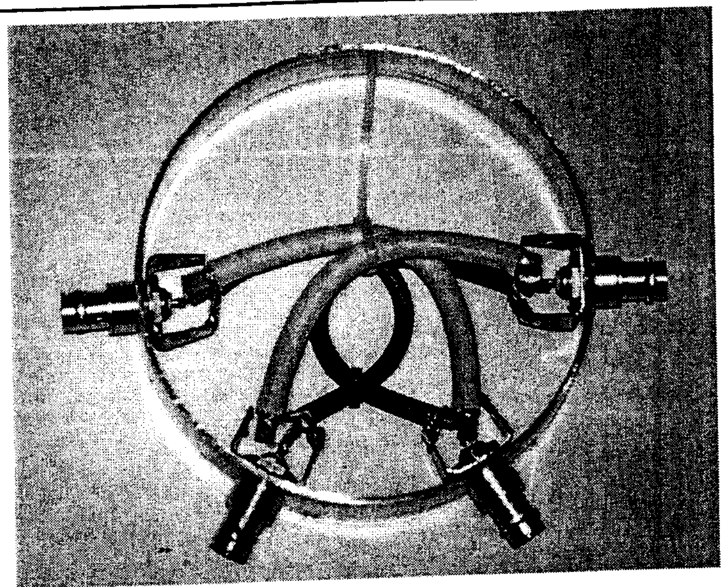

Fig 7 The Completed Hybrid Quarter Wave Circulator

3. Correct Dimensioning of the Hybrid Quarter Wave Circulator

Very few people know that this component can create a power division ratio which departs from 1. The scientific literature contains few descriptions of this characteristic. The disadvantage of this characteristic can be gathered from the scattering matrix using four-pole theory tools. The scattering matrix itself can be taken from [1]; the dimensioning guidelines can be derived from this. The results are shown in the Fig 6.

An analysis of this diagram provides information about how far division ratios can actually be achieved. So that as little as possible of the control power is lost, a division ratio as high as possible is selected. As the division ratio rises, ZL2 asymptotically approaches the value ZL = 50 Ohm. The associated value of ZL1 , however, no longer assumes a value which can be realised. So if practicability is our basic requirement, then any division ratios greater than 8 can be attained. For this ratio, we would need a lambda/4 coax section with an impedance level of 141 Ohms. This can be manufactured if the middle conductor is carefully extracted from a section of flexible 75-Ohm wire and if it is replaced by a piece of enamelled copper wire with 0.2 mm . Z then becomes 125 , which approximately corresponds to a division ratio of approximately. 6. Other Z values such as 50, 60 and 75 line can be obtained.

So the division ratios listed in the Table 1 can easily be achieved. Division ratios of under 1 would mean that the power at port 2 was higher than at port 3. In this event, we would need only to transpose ports 3 and 2. The table would then have to be determined for the reciprocal value of P3/P2.

4. Measuring Results from Assembled Hybrid Circulator

The hybrid ring described was assembled. For this purpose, a large-diameter section of aluminium piping was sawn off and faced. 4 coax sockets should be fitted onto the piping. This structure has proved its worth, because it allows for cabling without intersections. The division ratio was set exactly as determined. The conjugate complex tuning with the input reactive impedances of the VHF high-level stage allows the input reflection factor at port 4 to become infinitesimal (SWR: 1.1).

All lambda/4 circuit sections are cut to 11.5 cm. in the 70-cm band, with consideration being given to the velocity factor (v = 0.66). The 141-Ohm circuit is created as described. In the 23-cm. and 13-cm. bands, it is advantageous to create the hybrid using stripline technology. In still higher bands, it is better to use ¾ lambda stripline technology to produce the module. Make sure that the ¾ lambda circuit has the same transformation characteristics as the lambda/4 circuit. The circuit lengths for the GHz range are easier to handle.

5. Literature:

[1] Meinke/ Gundlach: Pocketbook of HF Technology

G.Megla, UHF Technology

Thumm/ Wiesbeck, High-frequency Measuring Technology

Proceedings of 23rd GHz Congress, Dorsten 2000