Circular Polarized antenna feed
(For EME on 10GHz and 5.7GHz).

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On more than one occasion at the EME conferences, circular polarization was agreed to be to be the standard for Microwave EME, so to became used on bands where regular operation can be found. In fact at 1.3, 2.3 (and 3.4) it is the standard in use by all stations. On 5.7GHz there are good number of regular stations using circular while just a few others still remain on linear. On 10GHz the vast majority of stations are using linear polarization. The reason behind this situation is probably related to the fact that a linear setup is somehow seen to be more simple to construct, and the belief that depolarization is so high that the antenna polarizations employed are irrelevant. At the time this article was written, the situation is quite clear for 5.7GHz and circular polarization is the way to go. However, at 10GHz there are still some doubts and there is a need for further observations.
The two main problems are therefore the need for a suitable reproducible feedhorn design for 5.7GHz and 10GHz; and further tests on EME at 10GHz. This article tries to address essentially the first topic. Further tests over the EME path are certainly desirable, but we believe the data presented leaves not much doubt that circular is also the reasonable polarization scheme to adopt at 10GHz. Here we present a no-tune circular polarity feeder for parabolic dishes and some real EME tests done with a prototype.*

(By "no-tune" we mean no adjustments required for polarity-circularity. Impedance matching adjustments are required but that is a simple task to perform.)*

Some introductory comments.

It is clear that depolarization occurs at microwave EME and this effect increases with frequency. 10GHz is believed to be on the borderline where moving to circular polarization may no longer constitute an advantage. However, this argument is also assuming that a circular polarized feed setup would be more difficult than linear and would have higher losses, so that any possible small advantage of circular would disappear. Recent observations do indeed show severe depolarization in some situations and therefore little advantage would result from going circular. However, there are still some other situations where depolarization is not so severe. Also observations have shown that Doppler spreading is less severe when using circular polarization.

We realize that, depending on the conditions, depolarization figures as low as 1 or 2 dB are possible but most of the situations we had experimented had depolarization down by 6dB. These figures were not result of a systematic analysis so they are to be considered as an indication and further tests are indeed required.

EME is however a rather untypical telecommunication situation: just one dB advantage is still significant for most of us, and worthwhile to pursue. Just remember that a QSO is a heavily quantized entity: you **make it** or you **don't make** it.

Basic design.

The feed system is composed of three distinct parts: the orthogonal launcher or combiner, the polarizer, and the antenna feeder.

In a matched condition these three elements are independent of each other and can be designed independently. Not realizing this has been at the base of many misunderstandings about terminology and the actual hardware, and also the driving force behind the belief that it is difficult to build and to get a feed system working properly.

The orthogonal combiner has the function of coupling one port to vertical and the other port to horizontal polarization. Both ports can have coaxial terminations, or one can be coaxial and the other in waveguide, or both can be in waveguide. With both ports in waveguide the combiner is usually called an OMT (ortho-mode transducer). Both ports in waveguide also corresponds to the launching section of a 23cm W2IMU or VE4MA feed [1]. At medium or low power on 10GHz, it may be useful to have the TX port in coax, since all low power and medium power amplifiers and TWTs are also in coax, but to have the RX port in waveguide so it can be followed by a waveguide switch to have the lowest loss possible. Note that a N coaxial TX port would handle more than 250W of power with reasonably low loss.

The polarizer has the function of converting the linear polarized signals into circular ones and vice-versa. This is accomplished by delaying differently the two components of the linear signal, as seen from the polarizing section that is rotated 45 degrees with respect to the signal polarization. From circular to linear it is the same process but in the opposite direction. A detailed explanation of this process can be found in the literature [2] and is outside the scope of this article.

The antenna feeder is the part of the feed system that has the function to illuminate properly the dish surface. Requirements for this are determined by the geometry, and the desire to optimize the geometry for either gain or low noise. It is important to understand that this is totally independent from the aspects we are addressing in the present article. We presume that the user knows what will be a suitable feeder for his dish geometry, and will find or develop a suitable design for this part of the feed system.

In practical terms, if you already have existing feeder that properly illuminates your dish and gives good results, you should continue to use it with the new OMT and polarizer section described here. In the present article, both drawings and pictures show a scalar feeder for prime focus dishes, but of course that part would need to be different for offset dishes, for example.

The orthogonal transition (coax too WG or OMT)

On the drawing you can see an orthogonal section with one port in waveguide and another in coaxial. If you want both ports to have coaxial terminations, you just use the coaxial transition two times with 90 degrees rotation difference between the two. Distance between them is not critical as long as the matching section of the transition at the rear is complete before the beginning of the transition at the front (although since they are orthogonal their mutual influence should be very small). If you want both ports in waveguide, you may use a design of a standard OMT. An OMT all in waveguide is under test and will be published very soon.

Note that all linear ports (whether they are coaxial or waveguide) will need impedance matching for the whole setup to function properly. Tune the screws in front of the coaxial launcher for best impedance match. The waveguide transitions use a 3-screw tuner section for impedance match [3].

The polarizer section.

Several designs for a CP polarizer for 10GHz were possible, for example the dielectric polarizer, the squeezed waveguide, the screw polarizer (but not so interesting as it would be quite difficult to adjust properly) and the septum polarizer. Both the all-metal squeezed waveguide polarizer and the dielectric polarizer could be the basis for a simple no-tune design. The all-metal approach will result in virtually no loss, but the one using a dielectric would have some measurable losses, although small. Also in the no-tune category the septum polarizer would be worth considering, although we did not adopt that design as it has a different method for feeding in the linear polarizations.

The polarizer section adopted in the present design is a narrow metallic section at 45 degrees. This is a fixed, no-tune version of the well known squeezed waveguide polarizer, but without all the uncertainties in the tuning procedure. HFSS simulations of such a polarizer were conducted and showed reasonable bandwidth and tolerance to dimensions. The simulation results for the optimum dimensions are presented in Figures 1 and 2.

Figure 3 is the mechanical drawing of a full feed system, with one coaxial port and one waveguide port. As noted earlier, the feeder section is for a prime focus feeder, but is only an example; you should use whatever is more appropriate for the dish in question.

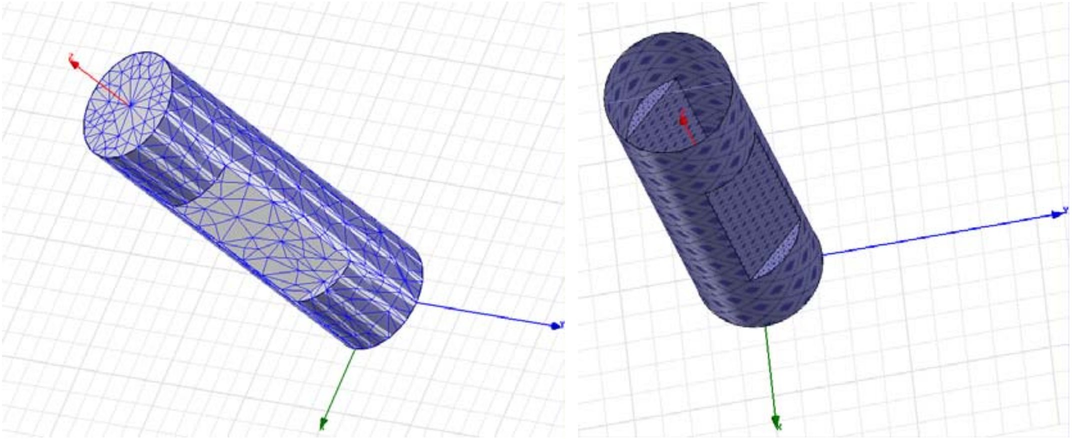

Figure 1 – Model and mesh used for HFSS simulation

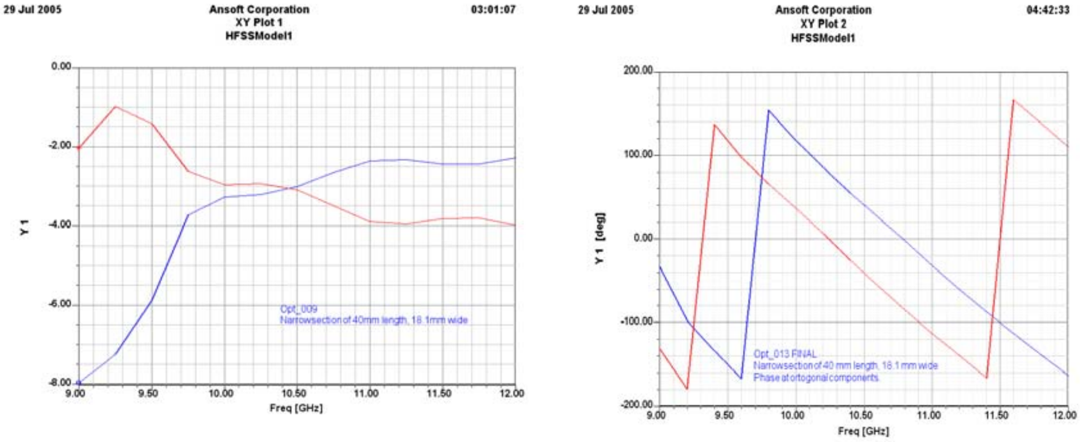

Figure 2 – Split power and phase difference between orthogonal components at the CP port, values used to help evaluating circularity.

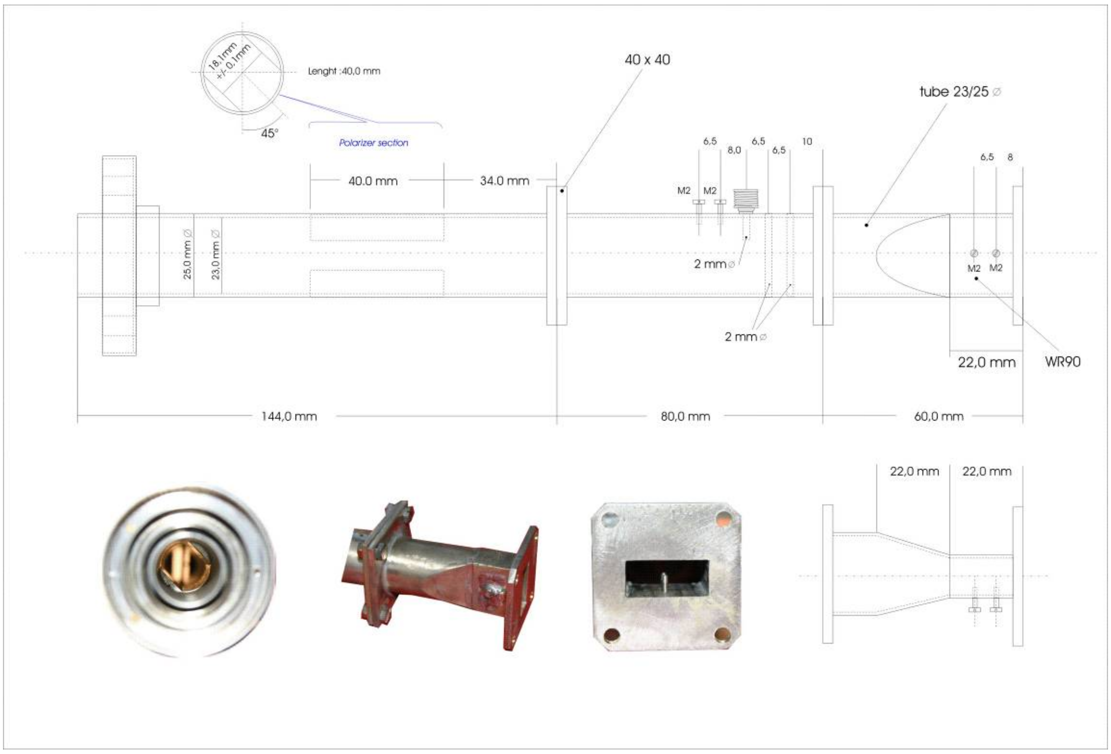

Figure 3 – CP feed system diagram that has a coaxial and a waveguide port.

The polarizer and feed designs can be found in more detail on CT1DMK's web pages at: http://w3ref.cfn.ist.utl.pt/cupido

Tests and measurements.

The measurements were performed on an HP Scalar Network Analyzer equipped with SWR bridge detector probes and calibrated receiving antennas. For the measurements of circularity all the antenna test set was covered by HF absorbing material to form an anechoic chamber.

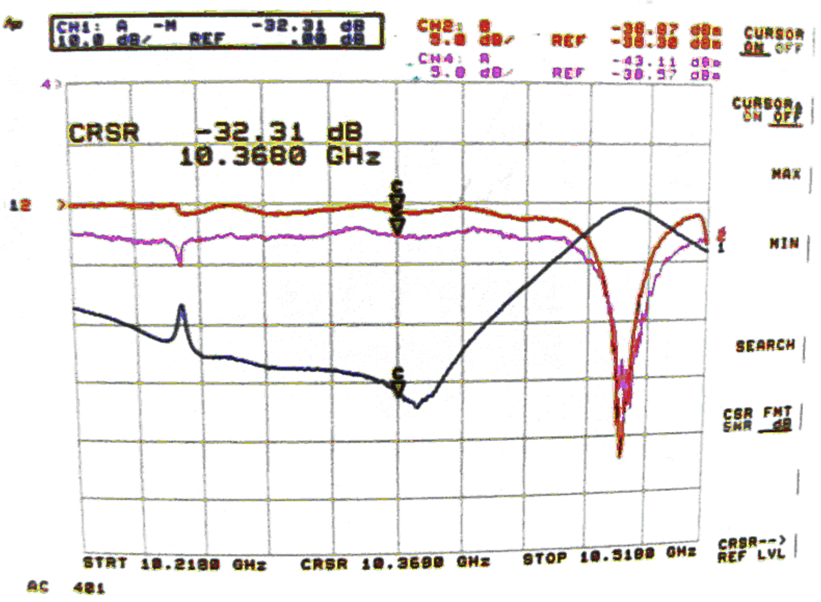

Figure 4- Network analyzer screen with the SWR on the TX- port (blue trace).

Tests consisted of analyzing the power arriving at the horizontal and vertical ports of a linear feed system while driving the TX port of the feed system described in the article. In Figure 4, the field strength at the horizontal measurement antenna is represented by the upper trace, and the field strength at the vertical measurement antenna represented by the lower trace (which was attenuated by 3dB to make the two traces easier to see). This measurement was verified by turning the TX port from 0 to 45° referred to the horizontal and vertical measurement antennas.

Figure 5- The circular feed assembly with choke rings positioned for an 0.3 f/D dish.

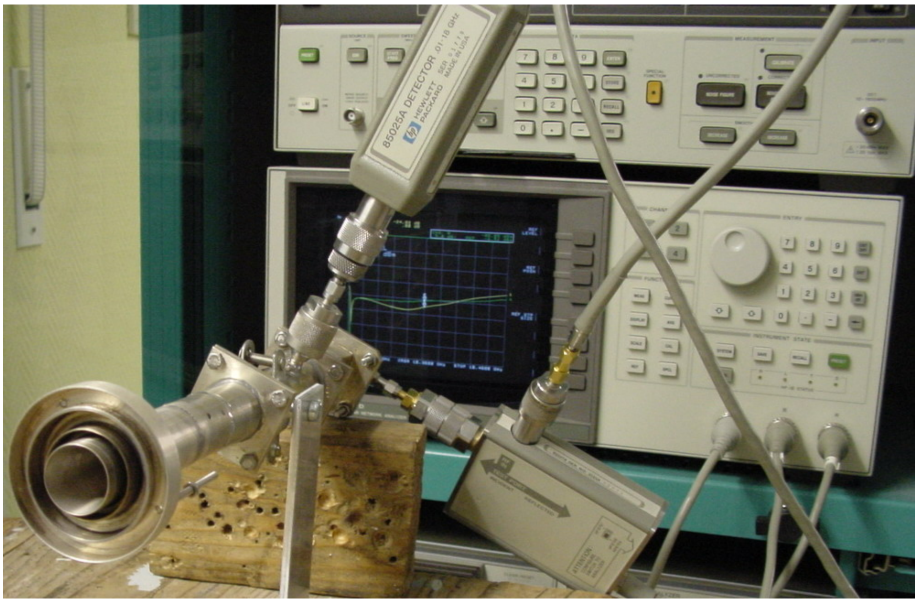

Figure 6 - Picture of the experimental setup, observable on the Network analyzer is the SWR on the RX (in yellow) and the isolation between the RX- port and the TX-port.

Measurement results:

Transmitter port return loss: -32dB *(after tuning by adjusting the matching screws)*

Receiver port return loss: -24dB *(after tuning by adjusting the matching screws)*

Circularity: better than 1,5dB *(there are no adjustments required for circularity)*

Isolation between RX and TX port: 23dB

Note: Do not peak for maximum return loss, always try to have broad matching.

Echo tests.

Echo tests on 10 GHz performed at LX1DB’s EME station, comparing linear and circular polarized signals, showed that the audio spectrum on the circular polarized echo signal was practically half the width of the linear polarized signals. The tests were performed with a transmission power of 100W on the feeds of the 3m dish, with the same RX for both polarizations and within a time window of 10 minutes (time to change the feed).

During the tests the weather conditions reported by the meteorological service was 8/8 cover by strato- cumulus clouds, a relative humidity of 85%, no rain and temperature 7°C. The moon position was in the range of an azimuth of 210° and an elevation of 55°. The Spectran program was used for the audio analysis and the data files clearly show the narrower bandwidth with circular polarization.

Linear to linear and Circular to linear EME tests.

Tests conducted by Willi LX1DB, Brian G4NNS, Chris GW4DGU and Philippe F2TU were done by using linear rotable polarization on reception and transmitting both on linear and circular. Results can be seen in Figures 7 to 10. Note the signals were corresponding to a CQ call hence the variation on the signal. We can use for our interpretation the peaks that correspond to series of dashes on the transmission.

On figure 7 and 8 we can see the signal received from a linear transmitting station while rotating the RX polarity. Figure 8 contains the same signal but representation is averaged and it is therefore much more easy to evaluate. If we take the peaks that correspond to individual dashes or series of dashes on the CW transmission and compare them with the average noise floor, the lower trace, we see a signal to noise ratio (S/N) of 6 to 7dB when polarization is aligned. However at orthogonal polarity we observe a S/N of only 1 to 2 dB. Off course this may not represent all possible situations namely at different relative moon position and very different antenna sizes, however worth to note this was a tipical EU/EU QSO using average antenna sizes and presumably representative.

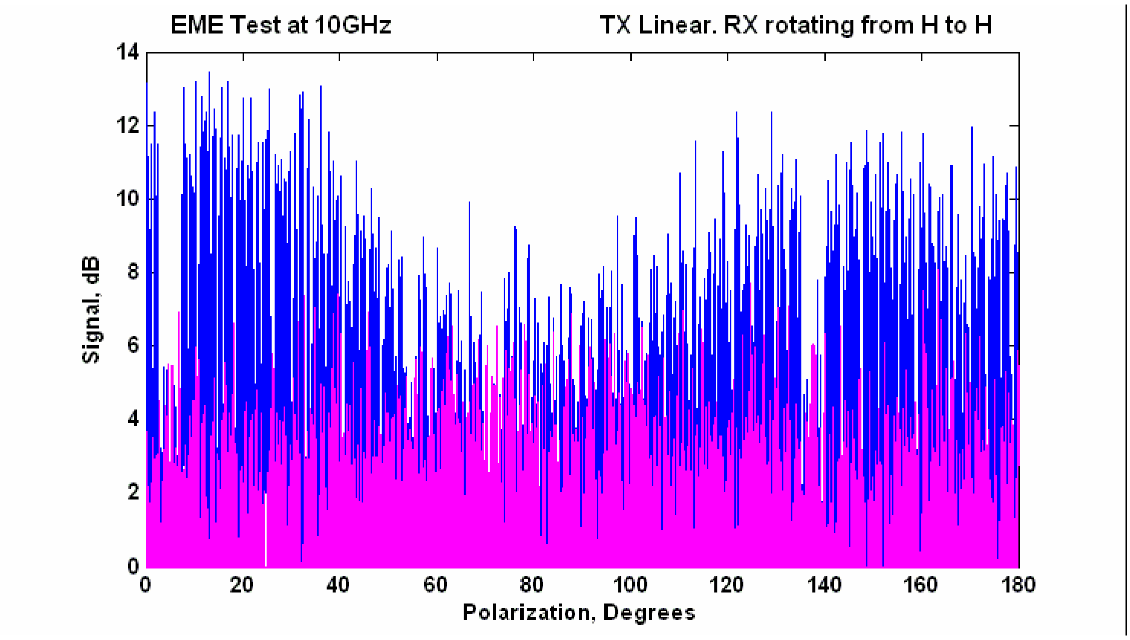

Figure 7 – Received signal in linear polarization while rotating the RX polarization, transmitting with linear fixed polarization. Signal power in dB over a 200Hz bandwidth, signal in black, system noise floor in grey.

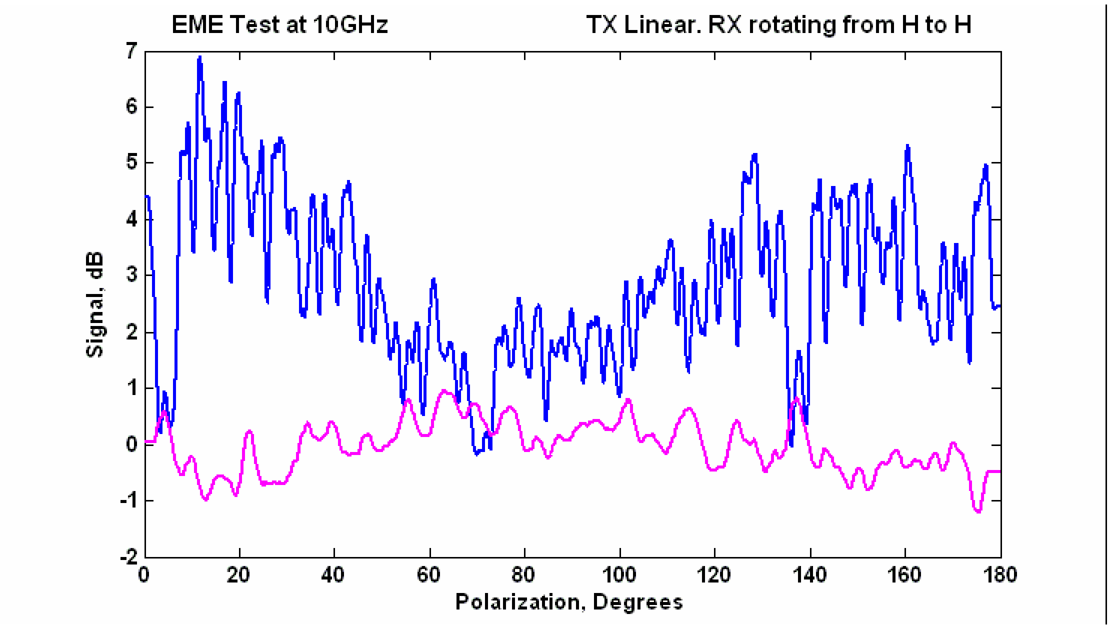

Figure 8 – Same as Figure 7 but with signal power averaging for better visualization/interpretation of the results.

On figure 9 and 10 the transmitting station was using RHCP while at the reception the polarity was being rotated. Figure 10 represents the signal power averaged. Again, If we take the peaks that correspond to individual dashes or series of dashes on the CW transmission and compare them with the average noise floor, we see now a signal to noise ratio (S/N) of 5 to 6 dB in the most favorable situation making a QSO between stations using different polarization schemes about 2 to 3dB below the optimum situation, this comes however as no surprise as this is what we would expect from the theory, that predicts 3dB if polarization is maintained up to 0dB (no advantage) if signal is totally depolarized. In this case we conclude easely that we are on a situation where only partial depolarization occours.

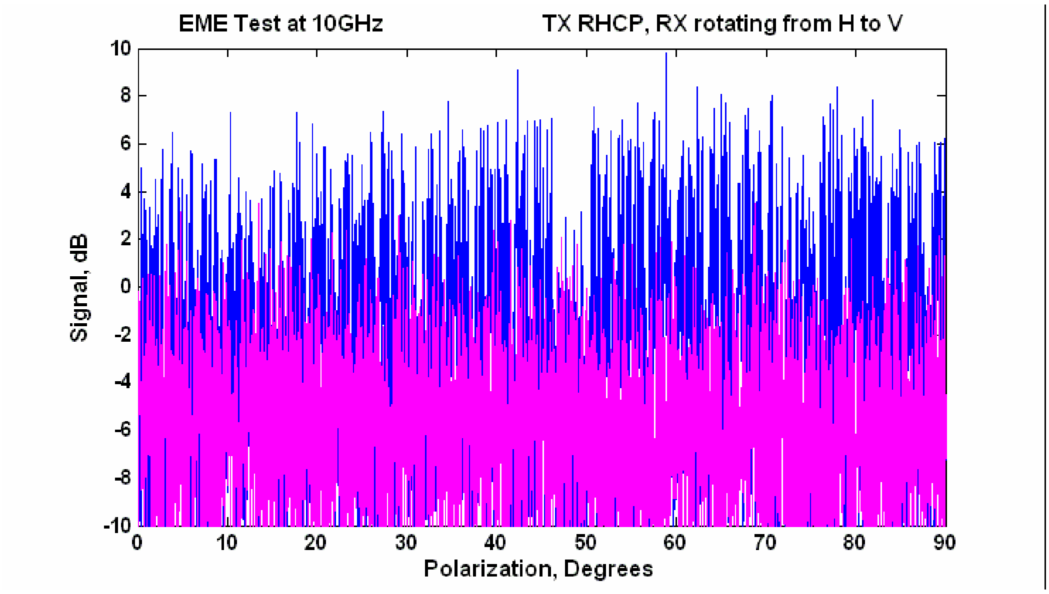

Figure 9 – Received signal in linear polarization while rotating the RX polarization, transmitting with RHCP polarization. Signal power in dB over a 200Hz bandwidth, signal in black, system noise floor in grey.

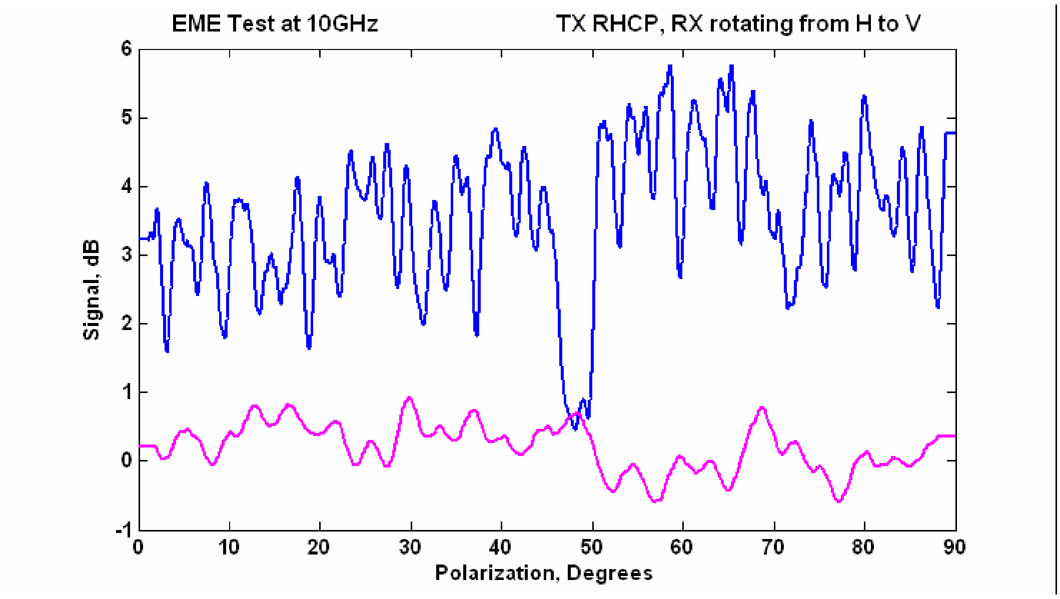

Figure 10 – Same as Figure 9 but with signal power averaging for better visualization/interpretation of the results.

Conclusions

The development of a orthogonal combiner (OMT) and a polarizer section was undertaken to meet the need for a suitable CP feed assembly to be used in EME on 10GHz. It was also a design aim that the construction should pose no difficulties for an average equipped mechanical workshop. The OMT section is based on well-known designs and construction principles. It can be made with both ports in waveguide, or with the RX port in waveguide and the TX port in coaxial. The design required no special attention besides the need for good impedance matching. The polarizer section was designed to allow easy reproduction without the need for adjustments for circularity, a feature that is essential to reduce the adjustments to only impedance matching.

From the experimental observations, we can indeed conclude that there is a worthwhile advantage in using circular polarization on 10GHz EME. With the data provided by the EME tests it was possible to observe 4 to 6 dB preservation of polarization, and a narrower received audio signal from CP in echo tests. Signals in circular to linear tests were about 2 to 3 dB below two well-aligned stations using linear polarization. However, 10GHz is probably the highest band where there is still an advantage of using CP over linear polarization.

References:

1– Microwave update -1999, procedings
2 – Foundations for Microwave Engineering - McGraw Hill
3 – Microwave Handbook , Vol. 3 - RSGB
4 – Electromagnetic Anechoic Chambers - Leland H. Hemming