970 Montee de Liesse, Suite 308
Montreal, Quebec H4T 1W7, Canada
Tel 514-335-6227 Fax 514-335-6287
E-mail: info@ focus-microwaves.com
Website: http://www.focus-microwaves.com

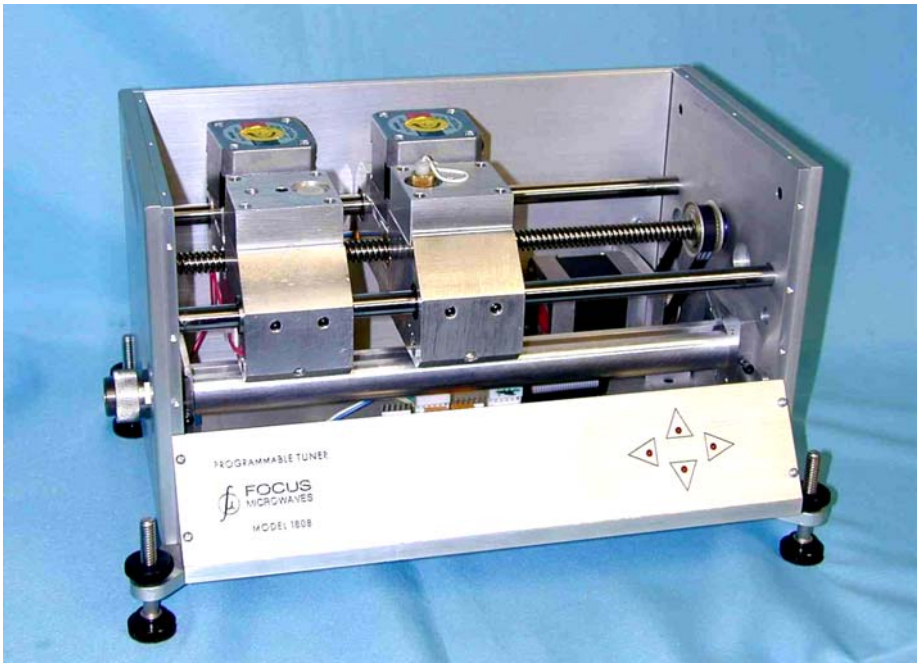
***Product Note 72***

# CCMT-SP: High VSWR and Accuracy 'Synchronized Prematching' Tuners*

Synchronized Prematching (SP) for automatic tuners is a new technique that provides:

- Instantaneous very high VSWR over a wide frequency range
- High Accuracy and RF power handling
- Full coverage of the Smith Chart at high Gamma
- Compact size
- Fast calibration capability (2-3 minutes/frequency)

CCMT-SP tuners are less expensive than normal Prematching Tuners (PMT) and use simpler calibration techniques and control. These tuners use the new concept of 'synchronized prematching'.




CCMT-1802-SP covers 2 to 18 GHz with VSWR ≥ 50:1 (20:1 at 2 GHz)

**Patent pending*


April 2002

# Tuning and Synchronized Prematching

We distinguish three basic forms of automatic tuning:

- Traditional single probe tuning (figure 2)
- Traditional Prematching tuning, uses two independent probes (figure 3)
- Synchronized Prematching (new) tuning uses two horizontally adjustable and vertically synchronized probes (figure 4).

Synchronized Prematching (SP) uses pre-matching techniques with two RF probes (slugs) controlled by the same tuner drive mechanism. The first slug creates a manually optimised prematching vector to the second slug and then both are coupled together for calibration and operation. Figures 2, 3 and 4 demonstrate the operation of the three basic types of tuning and prematching tuning. The shadowed area is the tuning area covered for either type of tuner.

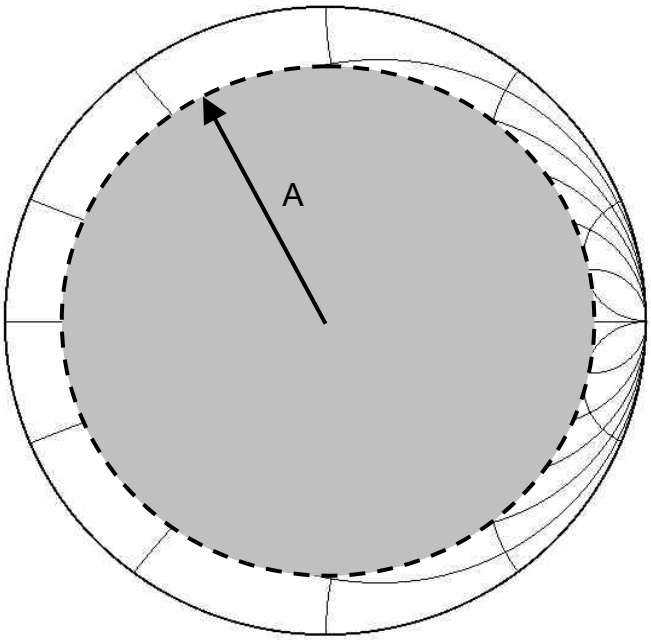



Figure 2: Traditional single probe tuning. The shadowed area represents the tuning range

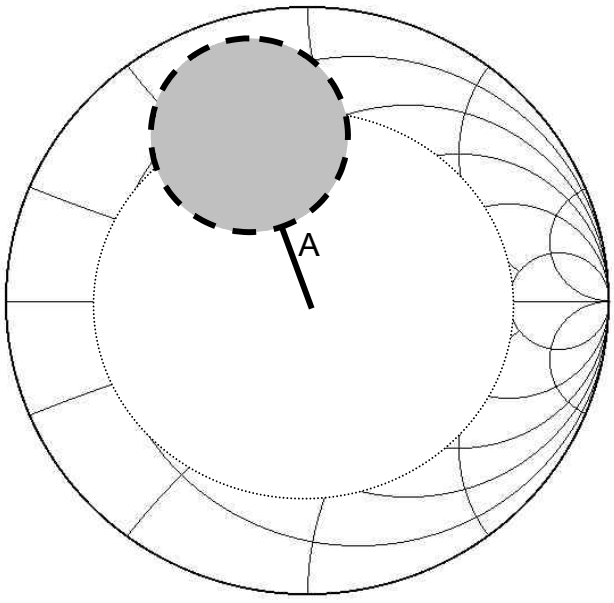



Figure 3: Traditional Prematching. Both reflection vectors A and B are independent: vector B tunes around prematching vector A

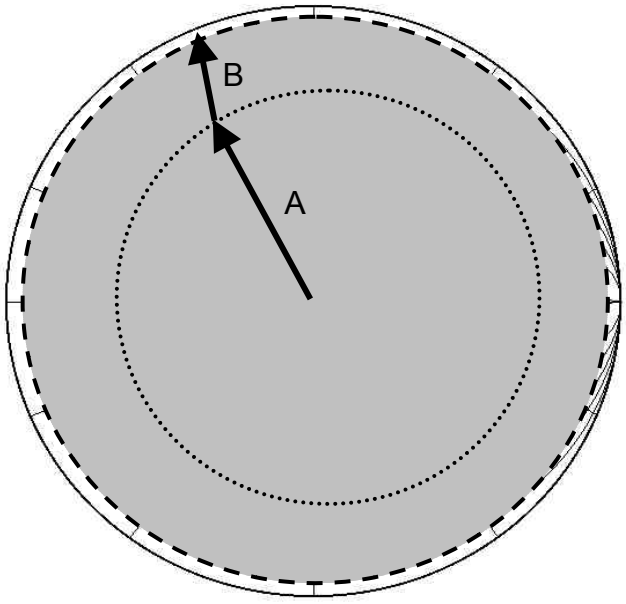



Figure 4: Synchronized Prematching. Both reflection vectors A and B are locked and turn together. Their relative angle changes only as a function of frequency

Synchronized prematching (figure 4) bears a number of advantages over traditional prematching, where both RF slugs operate independently (figure 3).
A major advantage is the fact that the physical distance between the two RF probes can be minimized, thus reducing the insertion loss of the transmission line between the two probes. This insertion loss is an important limiting factor of traditional prematching tuners at frequencies above 8GHz. Synchronized prematching tuners are therefore better suited for high frequency applications, at least up to 40GHz.

Compared with traditional prematching (PMT) tuners, synchronized prematching (SP) has a number of advantages.
SP tuners:

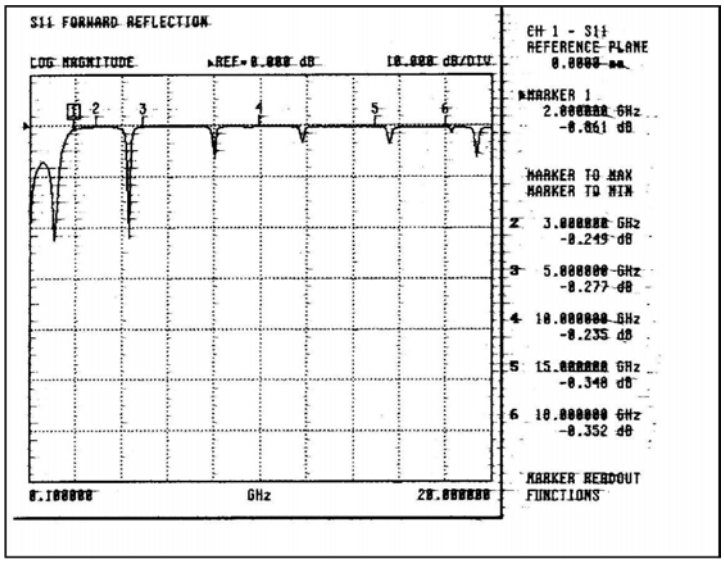
- Cover 360° of the Smith Chart at high VSWR, at all frequencies
- Have higher bandwidth, especially at high frequencies
- Are smaller in size and weight
- Generate higher VSWR at millimetre-wave frequencies
- Cost less
- Can be calibrated 50% faster

Synchronized prematching tuners have also the added advantages of traditional prematching tuners, which are created by the two interacting probes:

- High Accuracy at high VSWR [1]
- High RF Power due to prematching effect [1]

## Synchronized Prematching Performance Data

The following figures summarize the most important characteristics of SP tuners: Maximum VSWR (S11) over frequency, calibration point distribution and RF repeatability of tuners 2-18GHz and 3-40GHz.



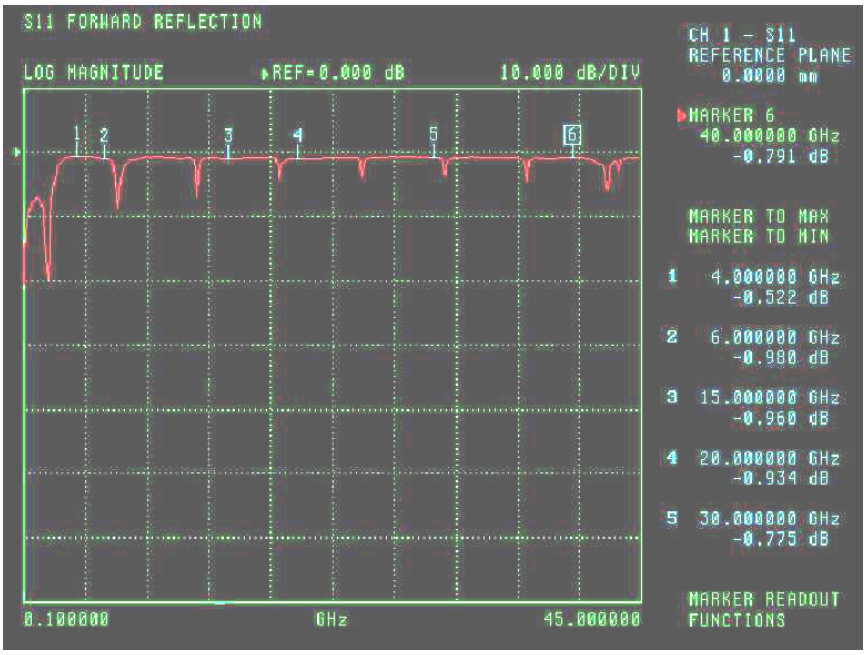



Figure 6: Maximum VSWR vs. frequency of 3-40GHz SP tuners

As mentioned in the introduction to this note the dips (resonances) in S11 can be shifted by simply manually changing the physical distance between RF probes. This means that, before a measurement campaign the user must check the situation of the tuner and decide if any of those dips fall close to the interested frequency. If so, the position of the movable carriage can be modified and locked such as to eliminate dips at all frequencies of interest. Because of the small frequency bandwidths of these dips, previous procedure is practically always possible. The tuner has then to be recalibrated.

Figure 7 shows typical distribution of calibration points of a synchronized prematching tuner at its maximum frequency of operation.
A minimum resistance of 1Ω can be tuned ($\Gamma \approx 0.97$) at all angles of the Smith Chart.

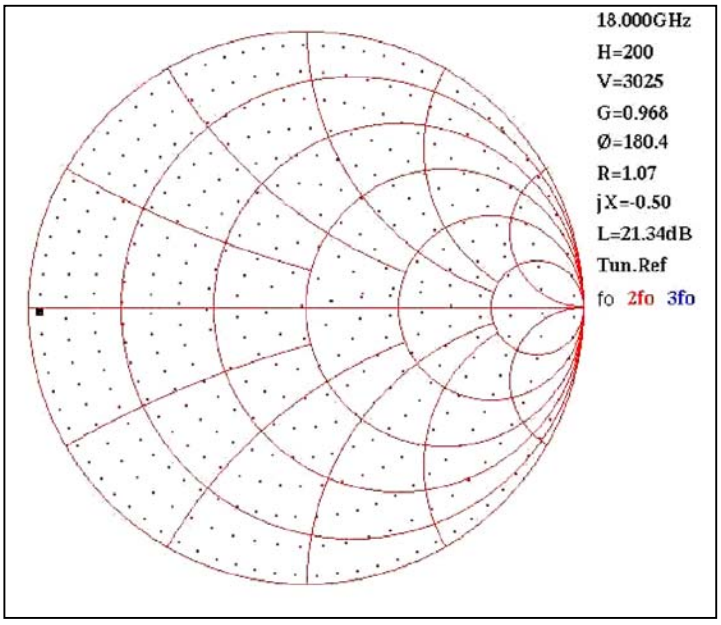



Figure 7: Calibration points of CCMT-1820-SP (2 – 18GHz) at the maximum frequency of 18GHz.

Due to the use of two RF probes to generate the high reflection factor, each probe operates at moderate reflection. This allows not only higher power handling but also higher repeatability and performance in tuning accuracy.
Data of RF repeatability is shown in figures 8 and 9.

The CCMT-1820-SP (2-18GHz) tuner has been calibrated at 18GHz for maximum VSWR, then its RF repeatability has been measured in terms of the difference in S-parameters between two sequential settings of the tuner, measured using a calibrated VNA.
Figure 6 shows the calibration points of the tuner, whereas figure 8 shows a contour plot of the corresponding repeatability error (in dB). Over the entire Smith chart we observe a maximum error of –50dB (indicated by a square on the chart at Γ≈0.96).

Another, more traditional, way to present the repeatability results is demonstrated in figure 9: It shows the repeatability error as a direct function of |Γ| only, without phase information.

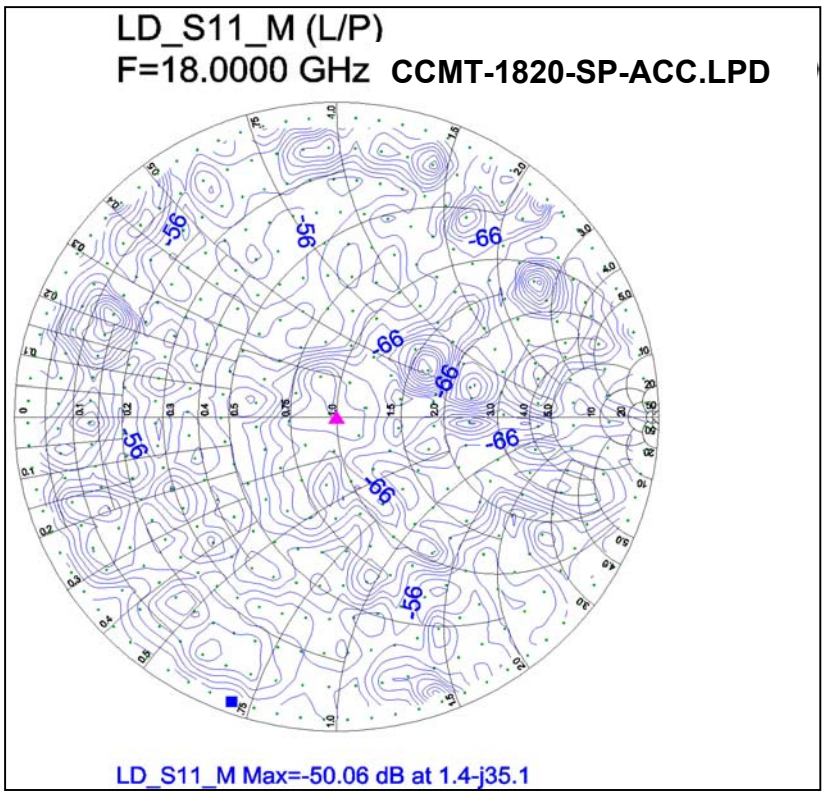



Figure 8: Repeatability Error ISO contours

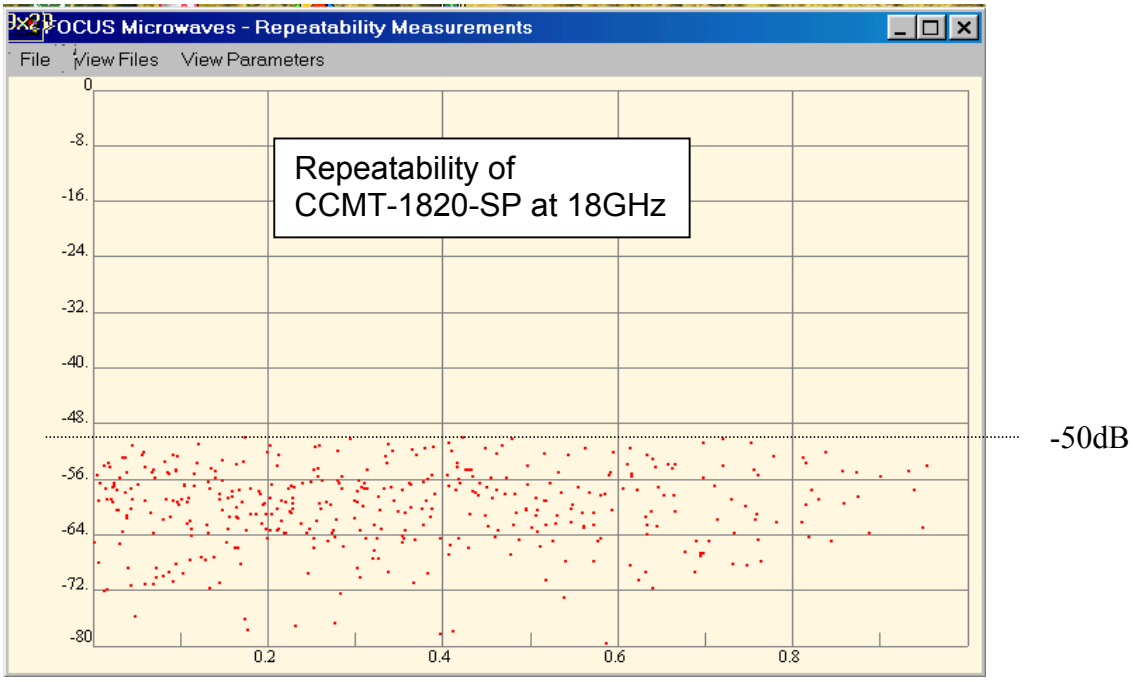



Figure 9: Repeatability Error (18GHz) as a function of Reflection Factor (S11)

# Comparison in Tuner Performance

This section summarizes experimental data on the maximum tuning range of two types of Focus tuners:

- Single Slug tuners
- Synchronized Prematching (SP) tuners

over the frequency ranges 2-18GHz and 4-40GHz.

| Frequency/GHz | 4.0 | 6.0 | 15.0 | 20.0 | 30.0 | 40.0 |
|---|---|---|---|---|---|---|
| Simple Tuner | 6:1 | 9:1 | 17:1 | 14:1 | 18:1 | 14:1 |
| SP Tuner | 34:1 | 20:1 | 20:1 | 19:1 | 23:1 | 34:1 |

Table I: Maximum tuning range of simple tuner vs. synchronized prematching tuner of the same size both rated 6-40GHz.

| Frequency/GHz | 2.0 | 3.0 | 5.0 | 10.0 | 15.0 | 18.0 |
|---|---|---|---|---|---|---|
| Simple Tuner | 5:1 | 8:1 | 16:1 | 29:1 | 25:1 | 18:1 |
| SP Tuner | 20:1 | 70:1 | 65:1 | 73:1 | 49:1 | 49:1 |

Table II: Maximum tuning range of simple tuner vs. synchronized prematching tuner of the same size both rated 2-18GHz.

# Conclusions

This note describes a new tuner type, called Synchronized Prematching (SP) tuner. This device uses two coupled RF probes and generates higher reflection factors over a wider frequency range then any other tuner described before with exceptionally high repeatability and tuning accuracy. Specimens in the 2-18GHz and 4-40GHz frequency range have been presented and compared with actual traditional tuners.